A REAL OPTIONS PERSPECTIVE TO ENTERPRISE ARCHITECTURE AS AN INVESTMENT ACTIVITY

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ABSTRACT

The ever-increasing expenditure on information technology (IT) is accompanied by an increasing demand to measure the business value of the investment. This has prompted enterprises to take an architectural view of their information systems (IS) and supporting technologies. However, many crucial enterprise architecture frameworks and guidelines are characterized by lack of adequate theoretical or conceptual foundations. Important but inadequately formulated concepts include architectural assessments, governance and architecture maturity models. These, though central to the enterprise architecture development process, remain in their current formulations largely wisdom driven rather than engineering based approaches. Absence of adequate scientific or mathematical foundations for enterprise design and engineering significantly impede enterprise architecture initiatives. The current body of knowledge is limited to reference architectures where the implementation challenges are left to the enterprises themselves.

This paper views enterprise architecture development as largely a process of decision making under uncertainty and incomplete knowledge. Taking value maximization as the primary objective of the enterprise architecture decision-making process, the paper attempts to develop guidelines for value enhancement. The paper assumes that portion of the value of enterprise architecture initiative is in the form of embedded options (real options), which provide architects with valuable flexibility to change plans, as uncertainties are

resolved over time. Plausibility of using such an approach to develop a better account of critical enterprise architecture practice is focused on three areas:

- The timing of critical architectural decisions;
- Architecture development for adaptability and change; and
- Phased approach to enterprise architecture maturity enhancement.

I. INTRODUCTION

Enterprise engineering[1] and integration are crucial components in architecting enterprises[2]. Large numbers of enterprise engineering initiatives are (reference) architecture driven. A reference architecture shows the anatomy of the life cycle of an enterprise (logical structure of activities). The common theme in all current reference architectures is the existence of the Enterprise Life Cycle concept [Bernus et. al., 2003]. This allows an enterprise to be conceptualized, conceived, designed, developed, operated, maintained and possibly retired (or renewed). Most reference architecture lifecycle representations revolve around these phases / activities.

A study of all existing reference architectures[3] reveals that many important enterprise architecture (EA) guidelines and best practices lack adequate theoretical or conceptual foundations. This is partly explainable by the fact that most of the developments of reference architectures have traditionally been driven by the industry where quick implementation is preferred over theoretical /

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[1] Enterprise Engineering is the collection of tools and methods that are used to design and continually maintain an integrated state of the enterprise [IFIP-IFAC Task Force, 1999].

[2] Words ***Enterprise*** and ***Organization*** have been used interchangeably in this paper.

[3] Prevalent reference architectures include: Architecture for Information Systems (ARIS), Purdue Enterprise Reference Architecture (PERA), Computer Integrated Manufacturing Open Systems Architecture (CIMOSA), Graphs with Results and Activities Interrelated / Integrated Methodology (GRAI / GIM), The Open Group Architecture and Framework (TOGAF), Federal Enterprise Architecture Framework (FEAF) and Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Framework.

conceptual rigor. In order to address such issues there have been a few significant efforts to concretize recommendations and best practices into generalized reference architectural approaches mainly by the International Federation of Information Processing (IFIP) and the International Federation of Automatic Control (IFAC), which proposed the Generalized Enterprise Reference Architecture and Methodology (GERAM) [Bernus and Nemes, 1996]. This proposal was then developed by the IFIP-IFAC Task Force and became the basis of the International Standard ISO 15704: 2000. GERAM defines a toolbox of concepts for designing and maintaining enterprises through their entire lifecycles [Bernus et. al., 2003]. It represents the common (baseline) set of requirements that other above mentioned reference architectures must fulfill in order to be GERAM compliant. All of the existing reference architectures mentioned earlier have been mapped to GERAM requirements [Noran, 2003].

Organizations embarking on an EA journey usually prefer to use one of the available reference architectures to speed up implementation and take advantage of collated best practices [Perks and Beveridge, 2003]. Concepts and guidelines in reference architectures, which are central to the architecture development process, remain in their current forms more heuristical than scientific. In practice, the lack of scientific or mathematical foundations for enterprise architecture significantly impede enterprise engineering for three primary reasons:

- The body of knowledge of the discipline appears informal rules of thumb rather than as principles based on underlying theories;
- It is extremely difficult to justify trade offs and crucial architectural decisions; and
- Recognizing flaws in or boundaries of applicability of informal heuristics is made difficult due to lack of adequate conceptual foundations.

Using Enterprise Life Cycle concept as the base and GERAM[4] requirement of an EA initiative to have a project based and methodology driven approach [IFIP-IFAC Task Force, 1999], this paper takes an integrated view of EA as largely a process of decision making under uncertainty and incomplete knowledge. EA literature stresses the need for EA initiatives to take value enhancement as the primary objective rather than technical perfection [Bernus et. al., 2003]. The traditional return on investment (ROI) expects costs of investment to be returned within the scope of the initiative at hand making it too tactical. Assessing the value of investments in EA, whose impact may not be apparent immediately, requires another measure. Gartner [2002] proposes the use of return on assets (ROA) as an alternative, which focuses more on value enhancement through increases in productivity of their capital assets.

With the above background, the first part of the paper is a brief discussion on the importance of economics in enterprise engineering with the view that enterprise architecture activity is one of investing valuable resources under uncertainty [Perks and Beveridge, 2003] with the goal of maximizing value added[5], rather than lowering total cost of ownership (TCO). While it is possible to adopt a complex view of value, the paper takes a more limited view of market value added to the enterprise. Economic value of an enterprise is greatly influenced by structure. The reason being that structure dictates behavior (including flexibility) that is displayed by an enterprise in the face of changing and uncertain business environment. Under such conditions flexibility in the architecture development process can provide great value by potential to avoid risks and take benefits of new opportunities as they come by. The paper discusses some of the uncertainties in architecting an enterprise and the

[4] To maintain generic applicability, this paper uses the GERAM requirements as the reference, however, at times in order to explain specific facts / issues, it uses The Open Group Architecture and Framework (TOGAF) v8.1 Enterprise Edition.

[5] Return on Enterprise Architecture measured in asset productivity [Gartner, 2002].

traditional approaches to address EA related economics.

The second part of the paper elaborates some of the available approaches to value flexibility and provides a brief overview of options pricing theory which is the basis for real options approach used in this paper. This approach is then discussed in the context of three critical areas: (1) options in timing of important architectural investment decisions; (2) compound options in architecture development process; and (3) options interpretation to architectural maturity levels. Five concrete real options are suggested as an approach to address some of the identified EA initiative risks.

The last and final part of the paper discusses some practical and theoretical challenges and difficulties that organizations may encounter in using the real options based approach to enterprise architecture investment analysis, including some of the factors that either encourage or impede its adoption. The paper concludes with suggestions for further research to address some of the challenges.

II. ECONOMICS-DRIVEN ENTERPRISE ENGINEERING

Traditional enterprise engineering focuses more on structure and technical perfection leading to lower TCO than value added (or asset productivity) [Gartner, 2002]. This paper takes the view that enterprise architecture development initiative is one of investing valuable resources under uncertainty with the aim of maximizing value added to the organization. This view is consistent with one of the documented business benefits of The Open Group Architecture and Framework (TOGAF) which mentions, “better return on existing information and reduced risk for future investments” [Perks and Beveridge, 2003]. While it is possible to adopt a complex view of value, this paper takes a narrow view: that value is measured in terms of asset productivity improved for the enterprise. This view is supported by the fact that according to Gartner, by 2007, IT asset productivity will drive market capitalization.

FROM STRUCTURAL PERFECTION TO VALUE ENHANCEMENT

The current heuristical and best practice based approach to enterprise architecture, though useful, has drawbacks. This stems from the facts, which are: (1) the primary focus of most EA initiatives is lowering the TCO, and; (2) the links between architectural concepts and decisions are at most qualitative, weak and subjective. The architectural concepts focus more on “how to structure the enterprise components” rather than “how to increase organizational value”. A look at the GERAM framework components in Figure 1 reveals that there is no component focusing on increasing organizational value [IFIP-IFAC Task Force, 1999]. Even TOGAF *Architecture Development Method* and *Architecture Continuum*, mapping to *Life Cycle* and *Life History* components in GERAM, respectively, is formulated in structural terms. These define the various groups of activities to be performed (life cycle) or temporality and succession (life history) concepts but with little mention about progressive enhancement of value added to the enterprise. There is currently no clear link between formulation of the architecture development model / methodology to a notion of value maximization.

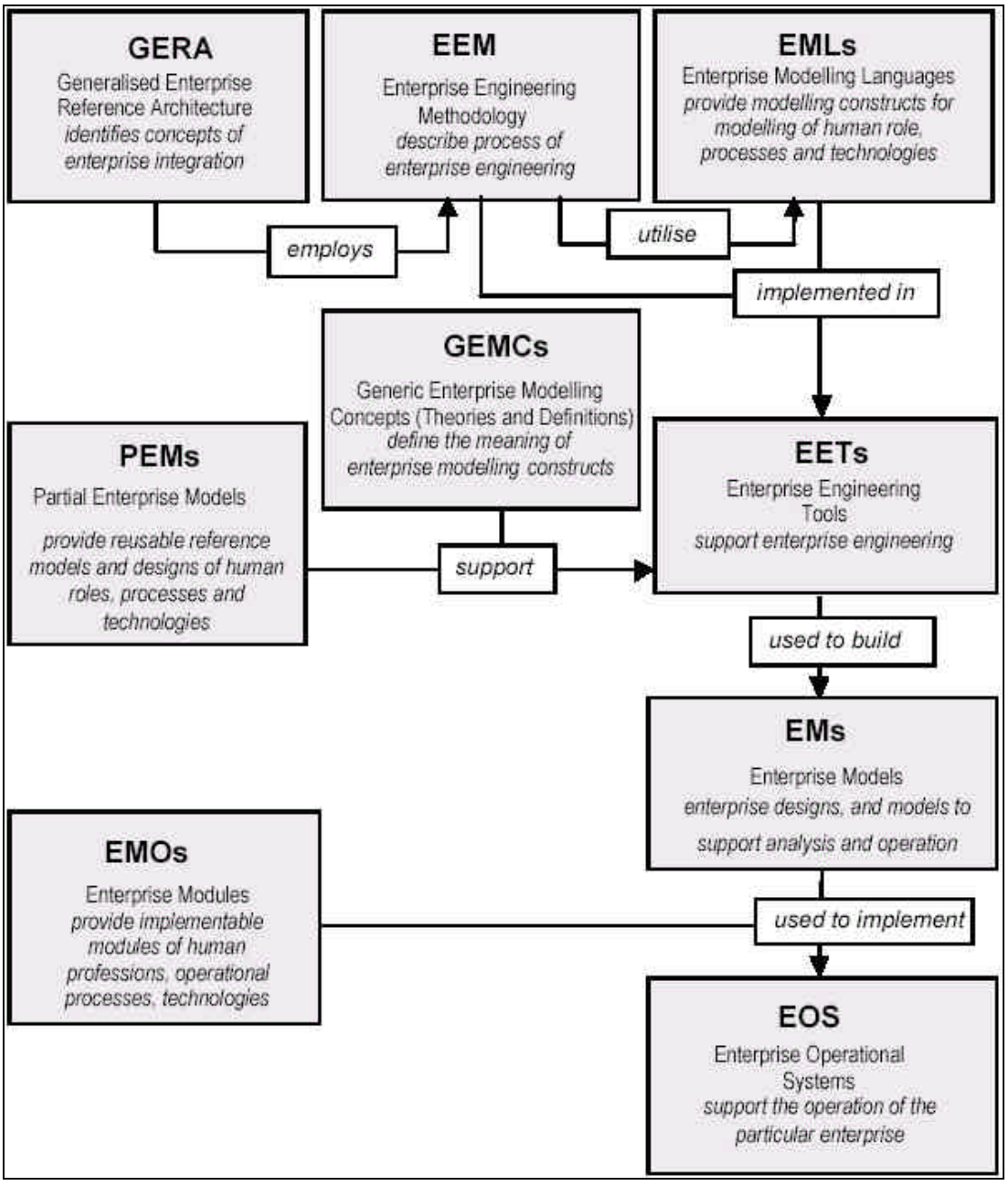


Figure 1. GERAM Framework Components[6]

With respect to timing of architecture related investments, most reference architectures rely on rules of thumb. TOGAF for instance provides a Standards Information Base (SIB) for enterprises to choose from a multitude of products

[6] Source: GERAM Version 1.6.3.

and standards to realize the enterprise architecture [The Open Group, 2003]. However, the need is to have a clear basis for reasoning about the timing of such investment decisions to have a better-founded approach to managing complex enterprise architecture initiatives. This need is driven by the fact that enterprises find it difficult to enhance their IT Investment Management Maturity [U.S. General Accounting Office, 2004] unless IT decisions are based on sound architectural factors.

STRUCTURE AND FLEXIBILITY IN ENTERPRISE ARCHITECTURE

The economic value of an enterprise is often influenced by its structure and methodology used in engineering the enterprise. This is due to the fact that the flexibility the enterprise has in order to incorporate changes depends on its structure. The capability to incorporate changes is necessitated given the changing and uncertain future business conditions. Thus flexibility provides great value to architects and is a desirable characteristic, which can provide both buffer against downside risks and exposure to upside opportunity. The ability to call off an initiative early in the life cycle in light of unfavorable new information minimizes the risk (and downside protection), while the flexibility to adapt the enterprise to take advantage of new business opportunities, by contrast, provides upside potential [Goranson, 2003; The Open Group, 2003]. Flexibility as an organizational capability is gaining increasing importance in areas of Architectural Thinking [Brown and Eisenhardt, 1998; Groth, 1999; Sauer and Willcocks, 2001; Weill and Vitale, 2002; Sauer and Willcocks, 2003]. Further, the need for flexibility is consistent and well in line with the EA Management Maturity Framework (EAMMF) of the U.S. General Accounting Office identifies ‘ability to leverage EA to manage change’ as a highest maturity level characteristic [U.S. General Accounting Office, 2003].

UNCERTAINTIES IN ENTERPRISE ARCHITECTURE

The aim of this paper is to develop a better ‘economics driven’ approach to value and its utility in enterprise engineering and enterprise architecture development.

The paper seeks to provide guidance to enterprise architects in deciding when to invest in flexibility of enterprise architecture and ways to exploit it effectively. Architects recognize the fact that during the architecture development process, uncertainty and incomplete knowledge are crucial. Often availability of additional knowledge with time has tremendous impact on architecture development. Aspects that create uncertainties in architecture development could include: cost and schedule, risk of operational failures, future business conditions and environment, future technology and standards development and adoption, technology incompatibility, user needs and value ascribed to those needs, adoption of governance guidelines and others [Perks and Beveridge, 2003]. Typically uncertainties include both endogenous and exogenous factors. The importance of flexibility in enterprise architecture can be seen with concepts like usage of Architectural Building Blocks (ABB) and Partial Enterprise Models (PEM) in assembling adaptable enterprise architectures [IFIP-IFAC Task Force, 1999; The Open Group, 2003]. The Enterprise Engineering Methodology (EEM) as specified by GERAM, requires reference architectures to provide a cyclic (spiral) process oriented phased approach to architecture development [IFIP-IFAC Task Force, 1999]. TOGAF Architecture Development Methodology (ADM), shown in Figure 2, and TOGAF Architecture and Solutions Continuum, shown in Figure 3, conform to GERAM requirements for EEM.

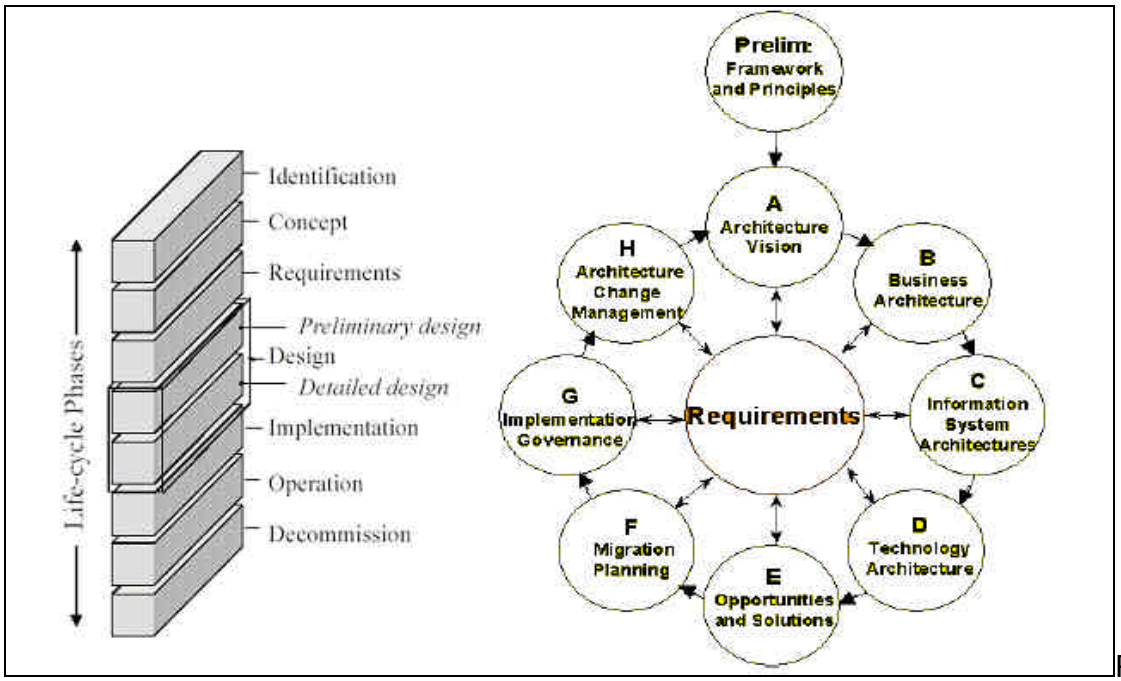
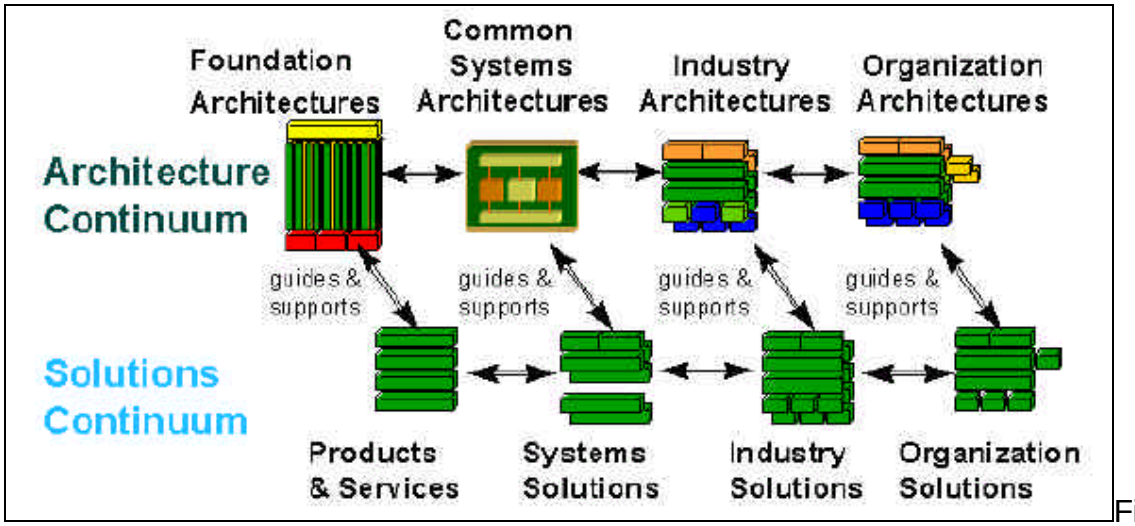


Figure 2. TOGAF Architecture Development Methodology with GERAM EEM

On one dimension TOGAF ADM imposes a phased structure on an architecture development initiative, where the aim during each phase is to discover / uncover new information and reduce key uncertainties, with decisions about whether to invest in subsequent phases. On the temporality dimension, TOGAF Architecture and Solutions Continuum stresses the development of alternatives, creating an option to choose the most appropriate one.



Figure

gure 3. TOGAF Architecture and Solutions Continuum[7]

Having architected for flexibility, the key decision for the enterprise is knowing when to take action in order to maximize enterprise value.

TRADITIONAL ENTERPRISE ENGINEERING ECONOMICS

The organization faces two crucial questions regarding the economics of flexibility:

- When should the investment to create flexibility be made such that it can be exploited in future at the appropriate time?
- When should the enterprise exercise this flexibility (i.e. the timing to exercise the option) such that it maximizes value?

In incorporating flexibility an enterprise has to weigh its cost against the value to make value-maximizing decision. The dilemma faced by most organizations that while the costs involved in architecting for flexibility are largely tangible, the value is hard to quantify, elusive and largely intangible. This is because potential payoffs due to flexibility occur in future, contingent on uncertain future conditions. This fuels the need for organizations to have an approach that allows comparison of real (tangible) costs to real (tangible) value by making present value of flexibility tangible.

Analyzing capital investments involves justification and assessment of these investments and it is frequently used as a criterion for investment decision-making or capital budgeting. Value is the single time-value discounted figure that represents all future net profitability [Mun, 2002]. Over time, value of an asset may or may not be identical to its market price. Traditionally, the three prevalent approaches to valuation of strategic assets include: the market approach, the income approach and the cost approach. The *market approach* views value of comparable assets in the market, assumed to be at an

[7] Source: TOGAF Version 8.1 Enterprise Edition.

equilibrium level due to market forces, as a way to value assets. Usually market approach looks at several criteria to make such assessments [Mun, 2002]. The *income approach* on the other hand looks at future cash flows and future potential profits, attempting to quantify such numbers to a present value. Some of the measurements include internal rate of return (IRR) and NPV. The cost an organization would incur should it decide to replace or reproduce the asset's future profitability potential, including cost of its strategic intangibles, is used in the *cost approach*. Despite availability of several approaches [Irani et. al., 1997; Wen et. al., 1998], assessment of investments in IT in general is still a fledgling practice [Keen, 1991; Banker et. al., 1993]. According to a survey conducted by Ballantine and Stray in 1999, the most utilized financial criteria to evaluate IT projects found that more than 25% of organizations use NPV method. The point to note is that all investment evaluation approaches look at IT in general and currently there are no specific approaches to assess and analyze investments in enterprise architecture initiatives. The most fundamental drawback is that static NPV fails to capture the future value of flexibility under uncertainty [Mun, 2002; Brach, 2003]. The associated investment decision rule is that investment should be made if the NPV is positive, otherwise not.

NPV approach is wrought with several problems that include undervaluing an asset due to lower cash in the shorter time frame, variability in the weighted average cost of capital discount rate and forecasting errors in assessing future cash flows [Coleman and Jamieson, 1994; Remenyi et. al., 1996; Mun, 2002]. The bottom line is that static NPV is generally not a good measure for valuing an enterprise because it tends to overlook one of the key sources of value: the flexibility of the enterprise to adapt to newly discovered and dynamic information, markets and environment.

II. APPROACHES TO VALUING FLEXIBILITY

The three main approaches to help make the value of flexibility tangible include:

(1) dynamic discounted cash flow analysis; (2) decision analysis (using utility theory), and; (3) real options. Each approach is appropriate under certain conditions and has its strengths and weaknesses. This paper uses the real options approach due to its suitability and wider applicability within the context of EA investments. The appropriateness of the real options approach will further be apparent as the paper progresses.

REAL OPTIONS APPROACH TO VALUING FLEXIBILITY

An organization's decision to investment in an EA initiative and enhance both its EA Maturity [Schekkerman, 2003] and EA Management Maturity (EAMM)[8] [U.S. General Accounting Office, 2003] includes actions embedded with options. Traditional approaches in investment analysis fail to capture flexibility, risks and contingencies that have the potential to impact business decisions [Copeland and Antikarov, 2001; Mun, 2002]. MIS literature has several papers that have proposed the use of Option Pricing Models (OPM) in IT investment analysis. DosSantos [1991] uses the Margrabe's exchange option model [Margrabe, 1978] for valuing a project utilizing a new testing technology. Kambil, Henderson and Mohsenzadeh [1993] use the binomial option pricing model as a decision making approach to proceed on a pilot project. Potential to provide a stronger foundation for architecture decision-making heuristics is a direct benefit of using option-pricing models. Another stream of research addresses issues related to investment timing rather than investment decision. Benaroch and Kauffman [1999] use Black-Scholes and Cox-Rubinstein models to investigate the problem of investment timing where the prime issue is not whether an investment is to be made but when the option held is to be exercised.

[8] From "A Framework for Assessing and Improving Enterprise Architecture Management Version 1.1" specified by the U.S. General Accounting Office (Document # GAO-03-584G).

	Stage 1: Creating EA awareness	Stage 2: Building the EA management foundation	Stage 3: Developing EA products	Stage 4: Completing EA products	Stage 5: Leveraging the EA to manage change
Attribute 1: Demonstrates commitment		Adequate resources exist. Committee or group representing the enterprise is responsible for directing, overseeing, or approving EA.	Written and approved organization policy exists for EA development.	Written and approved organization policy exists for EA maintenance.	Written and approved organization policy exists for IT investment compliance with EA.
Attribute 2: Provides capability to meet commitment		Program office responsible for EA development and maintenance exists. Chief architect exists. EA is being developed using a framework, methodology, and automated tool.	EA products are under configuration management.	EA products and management processes undergo independent verification and validation.	Process exists to formally manage EA change. EA is integral component of IT investment management process.
Attribute 3: Demonstrates satisfaction of commitment		EA plans call for describing both the "as-is" and the "to-be" environments of the enterprise, as well as a sequencing plan for transitioning from the "as-is" to the "to-be." EA plans call for describing both the "as-is" and the "to-be" environments in terms of business, performance, information/data, application/service, and technology. EA plans call for business, performance, information/data, application/service, and technology descriptions to address security.	EA products describe or will describe both the "as-is" and the "to-be" environments of the enterprise, as well as a sequencing plan for transitioning from the "as-is" to the "to-be." Both the "as-is" and the "to-be" environments are described or will be described in terms of business, performance, information/data, application/service, and technology. Business, performance, information/data, application/service, and technology descriptions address or will address security.	EA products describe both the "as-is" and the "to-be" environments of the enterprise, as well as a sequencing plan for transitioning from the "as-is" to the "to-be." Both the "as-is" and the "to-be" environments are described in terms of business, performance, information/data, application/service, and technology. Business, performance, information/data, application/service, and technology descriptions address security. Organization CIO has approved current version of EA. Committee or group representing the enterprise or the investment review board has approved current version of EA.	EA products are periodically updated. IT investments comply with EA. Organization head has approved current version of EA.
Attribute 4: Verifies satisfaction of commitment		EA plans call for developing metrics for measuring EA progress, quality, compliance, and return on investment.	Progress against EA plans is measured and reported.	Quality of EA products is measured and reported.	Return on EA investment is measured and reported. Compliance with EA is measured and reported.

Figure 4. Summary of EAMMF Version 1.1[9]

Given the high level of investments required to take advantage and optimize benefits of Enterprise Architecture, incorporating flexibility into EA investment decisions that accounts for active management and adaptation to changing market conditions, creates a more efficient and realistic investment framework. Also as EAMMF is a five level system (see Figure 4), each level representing

[9] Source: U.S. General Accounting Office (Document GAO-03-584G) April 2003, Version 1.1

higher degree of EA Management maturity, the possibility of options to move from lower to higher maturity levels do exist. These options can be called *EAMM Options*. However, application of OPM to capital investments in EA initiatives must address the following issues [Taudes, 1998].

- What is the kind of underlying asset and how is its value determined?
- What stochastic process is useful in describing the development of value, and how can its parameters be estimated?
- Can the “no arbitrage condition” be applied in the context being considered?
- What restrictions need to be placed on the general situation described above such that the application of OPM is useful in the EA context?

RATIONALE FOR USING REAL OPTIONS APPROACH

Decisive benefits provided by real options play a critical role in its being used in analyzing generic IT investments [Dixit and Pindyck, 1994] as all IT projects embed real options [Nichols, 1994; Trigeorgis, 1996] when it allows management to make future decisions about the project in response to changing market conditions and business environment. The need for managerial flexibility to support management decisions based on changing market conditions is also a critical requirement for EA initiatives. Thus the use of real options specifically EA scenarios is a natural extension. Rationale to use real options based approach within the context of EA initiatives include:

- *Accommodating Managerial Flexibility*: Business conditions are fraught with uncertainties, which usually get resolved through passage of time, allowing managers to make appropriate mid-course corrections to incorporate new information [Mun, 2002]. As decisions are made at each phases of the architecture development initiative, allowing for flexibility better addresses EA initiative uncertainties. Decisions are enriched with information that is available as the initiative progresses. This provides critical inputs to design new investment configurations. By making an initial investment in flexibility, an organization reduces the cost of altering its strategy [Miller and Waller, 2003].

- *Alignment with Investment Lifecycle*: The EAMMF is a five level system that includes several Critical Success Attributes (CSA) and Core Elements (CE). The five levels are akin to a multi stage project where an organization can decide to move up the stages based on results of the preceding stage. This allows organizations mulling investments in EA, to stage it as per EAMM levels, thus facilitating alignment of the EA initiative lifecycle with investment lifecycle.
- *Discovering and Building Innovative Investment Configurations*: Discovering and embedding options within investments is a crucial and planned task that allows organizations to configure investment in order to address business risks [Benaroch, 2002]. This facilitates customizing investment configurations based on known and unknown characteristics of the specific program under consideration and discourages boilerplate 'one-size-fits-all' inflexible approach, which is typical in traditional discounted cash flow approaches. With real options the focus shifts from 'detailed planning' upfront to 'sensing and responding' as the initiative moves along.
- *Characteristics of EAMMF based EA Initiative*: The fundamental notion of real option analysis i.e. value of flexibility to address uncertainties, is suitable for projects and programs characterized by large investments, extended timeframes, significant uncertainties, large number of intangible benefits that are subject to rapid deterioration if timing is wrong [Brach, 2003]. An EA initiative displays all of the above thus becoming a natural candidate for real options approach.
- *Compatibility with Traditional Approaches*: A real options analysis reduces to the traditional NPV analysis if flexibility is removed[10] [Taudes, 1998; Copeland and Antikarov, 2001; Mun, 2002]. This encourages organizations familiar with traditional approaches to adopt real options approach, as they are able to 'see' the link.

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[10] Active NPV (NPV^A) = Passive NPV of Expected Cash Flows (NPV^P) + Value of Flexibility from Active Management.

III. FORMALIZING RISK AND UNCERTAINTY

In statistical decision theory risk is defined as “the expected value of a loss function”. Risk is commonly measured in terms of consequences and likelihood, where likelihood is a qualitative description of probability or frequency. In the context to risk, it is critical to note that risk arises from choice [Emblemsvag, 2004]. Three crucial facts associated with risk are:

- Risk gives negative associations
- Risk is a probabilistic phenomenon
- Uncertainty is the source of risk

This brings us to concept of uncertainty, which is defined as “the lack of information and knowledge” or “the state of being uncertain, in doubt or hesitant”. Uncertainty exists is all situations that are unknown, unpredictable, open ended or complex.

INCREASE UNCERTAINTY TO LOWER RISKS

As is evident, risk and uncertainty are closely linked. However, increasing uncertainty can actually reduce risks and vice versa. This phenomenon can be explained by the fact that uncertainty and complexity are closely linked and produce an undesirable side effect for decision makers, which is lack of precision. This has been formalized as *Law of Incompatibility*, which states that “as complexity increases, precise statements lose meaning and meaningful statements lose precision”. This means that increasing uncertainty in the decision making process and associated analyses to better reflect true uncertainty actually lowers risk or ignoring complexity and / or uncertainty is risky.

Uncertainty and the value of flexibility in the face of uncertainty are at the core of both enterprise architecture development and finance. Reducing risk by introducing uncertainty is what this paper proposes and it uses Monte Carlo

methods to achieve this. Monte Carlo methods usually rely on introducing uncertainty into the models since no uncertainty exists, allowing assessment of the impact of uncertainties on the outcomes. The exact use of Monte Carlo methods in the context of EA decision-making is elaborated in a later section.

IV. QUALITATIVE ARCHITECTURE PRINCIPLES

Enterprise architecture development is based today largely on experience and heuristics. Reference architectures like ARIS, PERA, CIMOSA, GRAI / GIM, TOGAF, FEAF typically provide architecture principles as an aid to the architecture development process. Architecture principles are general rules and guidelines, intended to be enduring and rarely modified, which support the deployment of all IT resources and assets across the enterprise, reflecting a level of consensus among the various elements of the enterprise [The Open Group, 2003]. Developed from generic IT principles, architecture principles are usually of two types [The Open Group, 2003]:

- Principles governing the architecture development process
- Principles governing the architecture implementation process

A study of TOGAF Version 8.1 and Federal Enterprise Architecture Framework (FEAF) Version 1.1 which specify 20 and 8 architecture principles, respectively [CIO Council, 1999; The Open Group, 2003], reveals that principles are: (1) Qualitative and not based on documented scientific or mathematical theories; (2) Focus of aspects like decision making, prioritizing, linkage to business objectives, and prudent management of investments among others. In general, the need to delay decisions for as long as possible can be inferred (directly and indirectly) from several architecture principles like: *maximizing benefit to the enterprise, aiming technology independence, requirements based change, displaying responsive change management, coordinating technology investments* and *controlling technical diversity*. Under these conditions, use of options pricing theory presents potential to understand why architecture

principles seem to work, to explore conditions in which they are / are not valid and to develop prescriptive models for architecture decision making. This is made possible as real options thinking make key variables linked to value of decision flexibility under uncertainty, explicit. Understanding the underlying mathematics in architecture principles allows organizations to reason on when, why and how to apply a certain principle and what results are to be expected.

V. AN OPTIONS INTERPRETATION OF ENTERPRISE MODULES

Enterprise modules are implemented building blocks, which are utilized as common resources in enterprise architecture development [IFIP-IFAC Task Force, 1999]. A building block is a package of functionality specified to meet business requirements [The Open Group, 2003]. TOGAF for instance identifies to types of building blocks, Architecture Building Blocks (ABB) representing bundles of functionality and Solutions Building Blocks (SBB) that represent real products and custom developments. Building Blocks / Enterprise Modules are characterized by:

- Public interface(s) to access functionality
- Interoperability with other building blocks
- The capability to support assembly of the system from a set of building blocks

As is evident from the characteristics above, Enterprise Modules / Building Blocks actually facilitate implementation of several architecture principles. Having discussed earlier the application of real options to decide on the optimal time of architecture investment (value of timing), this section focuses on value of modularity. Although real options have not been used in enterprise architecture activities, it is interesting to see the existence of embedded options when designing enterprises in a modular manner. As seen earlier, the primary idea to facilitate enterprise module development is to enhance the ability to assemble enterprise entities from a set of available building blocks. Thus enterprise

modules (i.e. ABB) create options to select the best solution from a set of solutions (SBB). Solution variants are usually developed by experimentation, and the challenge is to create real options for enterprises (architects) to modify internal details without impacting the rest of the system (as long the interfaces of the SBBs do not change). This makes investment in developing building blocks provide benefits that can be expressed as the value of such an option. The actual specification and development of building blocks takes place at two levels, shown in Figure 5:

- At the context level (which includes *business process* and *technical functionality and constraints level*)
- At the implementation level (which includes *architectural model* and *solutions model* level)

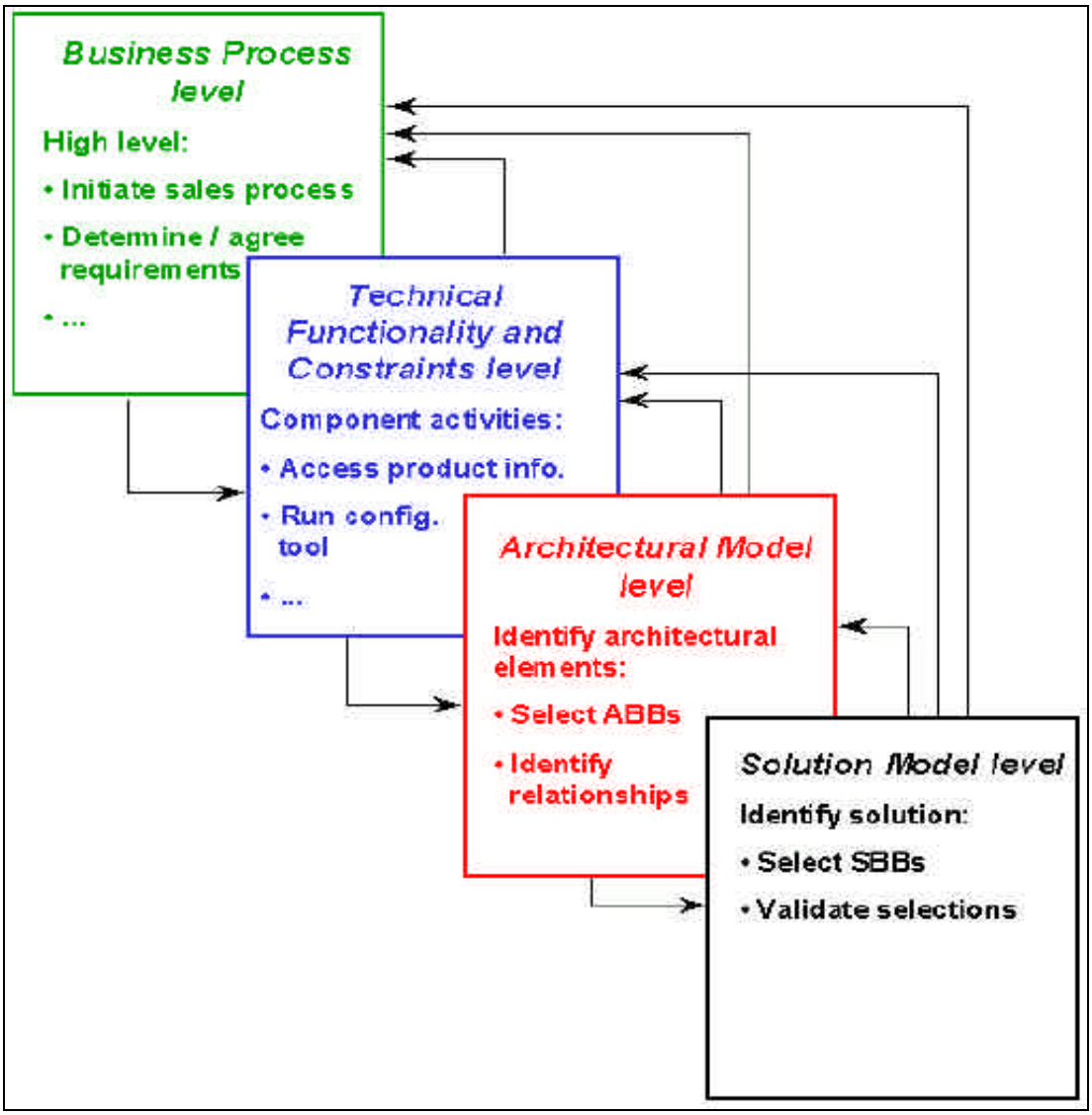

Figure 5. Iterative Modeling for Development of Building Blocks[11]

VI. METHODOLOGY FOR ENTERPRISE ARCHITECTURE INVESTMENT MANAGEMENT

Typically EA initiatives consist of steps that include: needs identification, concept development, requirements analysis, preliminary and detailed design, implementation, operation and decommission. In addition to life cycle phases, EA development involves understanding the needs of different (and relevant)

[11] Source: TOGAF Version 8.1 Enterprise Edition.

stakeholders and incorporating their perspectives. These stakeholders' perspectives are called 'views'. The detailed representation of the EA development lifecycle and various views are shown in Figure 6.

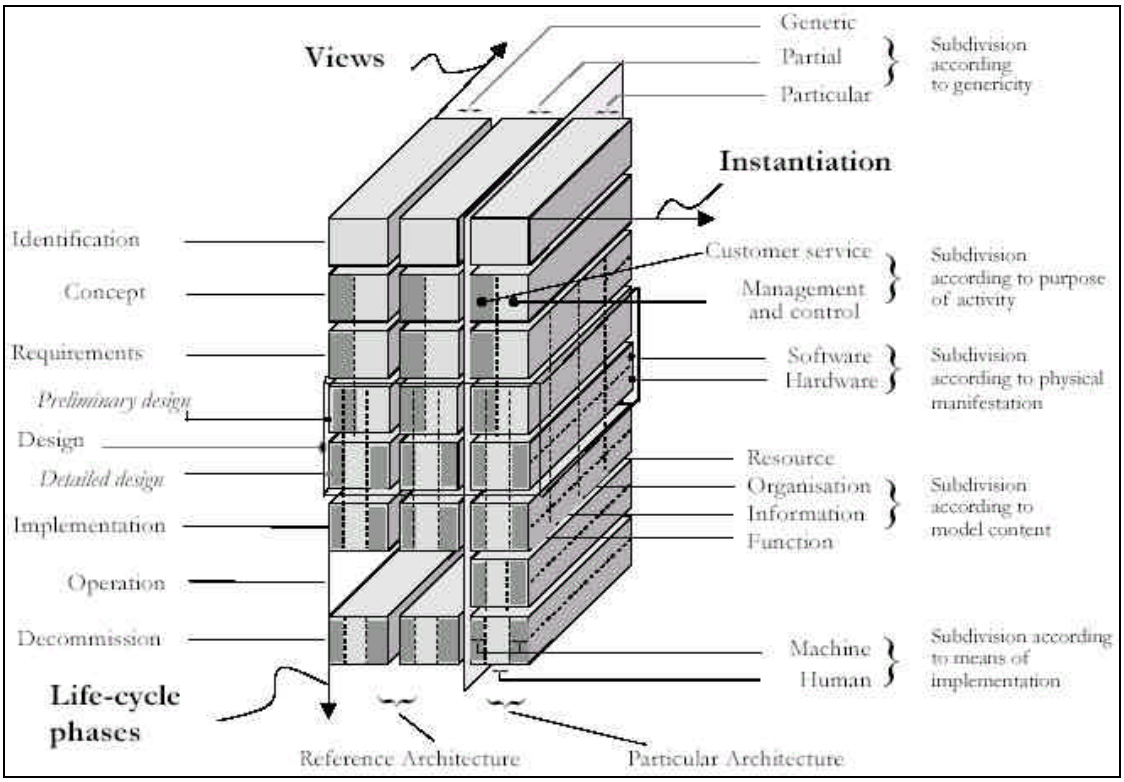

Figure 6. Detailed EA Development Lifecycle Phases and Supported Views[12]

Any methodology proposed for investment management of EA development activities must synchronize with the overall EA initiative, as it is imperative to understand broadly the EA initiative in order to develop a reliable and acceptable investment management methodology for it. The proposed methodology, adapted from IT investment methodology put forth by Kulatilaka, Balasubramanian and Storck [1999] consists of eight steps: (1) assessment of current capabilities, (2) identification and specification of desired capabilities, (3) design of a contingent investment program to attain desired capabilities, (4) estimation and valuation of costs and benefits of realized capabilities in terms of cash flows, (5) modeling uncertainties using event trees, (6) identification and

[12] Source: GERAM Version 1.6.3.

incorporation of managerial flexibilities using decision trees, (7) performing real options analysis (ROA) and an *optional* (8) optimization of portfolio and resources. As the primary benefit of embedding real options within the investment process is to allow managerial flexibility, addressing investment risks is a critical factor [Wen et. al., 1998; Benaroch, 2002]. Hence, the proposed investment management methodology based on real options approach, elaborated in the following sections, incorporates management of investment risks through introduction of uncertainties. The following subsections elaborate each of the eight steps.

ASSESSMENT OF CURRENT CAPABILITIES

Assessing current capabilities takes several critical inputs from EA development initiative. Capabilities are driven by business needs, hence understanding existing capabilities provides insight into resources and competencies that organization currently has. Resources are generally “what the organization has access to” and competencies are “what the organization does well” [Warren, 2002]. The reason it is critical to understand current resources and competencies is because an organization most fundamentally attempts to build up new resources and competencies from existing resources and competencies [Warren, 2002]. As business capabilities are dependent on resources and competencies, an organization has an associated value for every business capability and attempts to acquire new capabilities have associated investments. In addition to taking a resource-based view [Wernerfelt, 1984] to an organization, techniques that are useful in this step include a Strength, Weakness, Opportunity and Threat (SWOT) analysis [Porter, 1985] and Balanced Scorecard (BSC) analysis [Kaplan and Norton, 1996].

IDENTIFICATION AND SPECIFICATION OF DESIRED CAPABILITIES

Desired capabilities are what an organization secures after making a series of investments, where the actual investment cycle could be split into several stages with the decision to proceed on each stage depending on the outcome of

the preceding stage. The gap between current capabilities and desired capabilities is what determines the quantum of investment required. Securing desired capabilities is important to an organization as these can potentially provide several benefits and payoffs (both short and long term) that the organization rationally yearns for. To maximize such benefits and payoffs, the investment management methodology must provide for taking advantage of changing market conditions, seek and seize impending opportunities and mitigate down side losses. While for an enterprise it is beneficial to link and align EA development to overall business goals and objectives, it is crucial that the target architecture is specified against EA Maturity [Schekkerman, 2003] and EA Management Maturity [U.S. General Accounting Office, 2003] frameworks. Maturity frameworks provide reference points against which enterprise capabilities can largely be objectively compared. Specifying target capabilities against such frameworks also allow enterprises to identify areas for improvement in the next round of EA development.

DESIGNING AN INVESTMENT MANAGEMENT APPROACH

It is highly unlikely that an organization would design an investment just for the EA initiative. Typically organizations have investment programs relevant for any and all potential investments in IT. A comprehensive IT investment management approach is the investment control process developed by the United States General Accounting Office [U.S. General Accounting Office, 2004]. It is a three-phase investment process as depicted below in Figure 7.

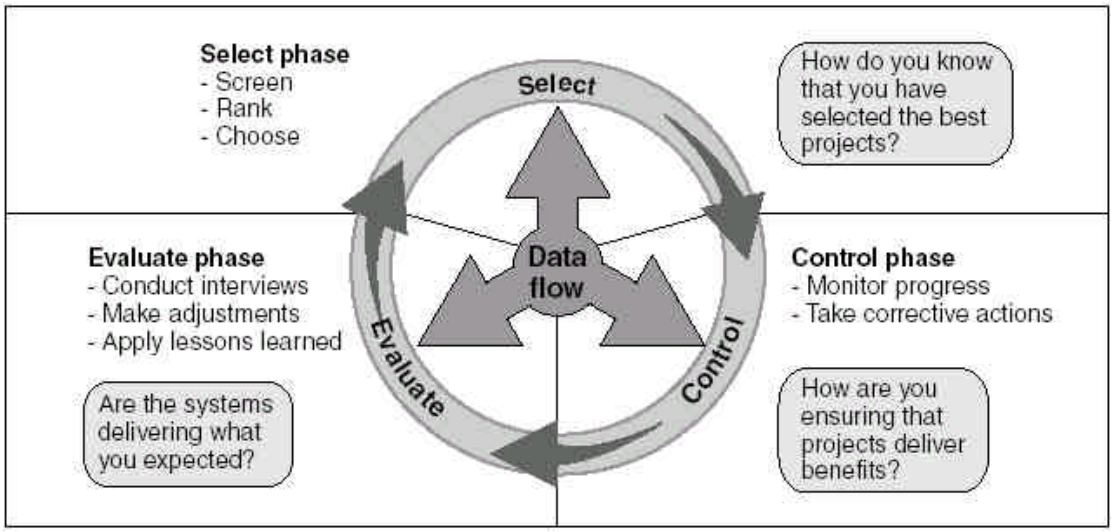

Figure 7. Phases of IT Investment Approach[13]

While there are several activities involved in each of the above phases in Figure 7, the following sections will only elaborate those that are relevant in the context of an EA initiative. Real options based investment analyses elaborated in subsequent sections would largely be used to *select* options and provide basis for *control* and *evaluation*.

ESTIMATION AND VALUATION OF COSTS AND BENEFITS

This step in the investment management process involves determining the incremental cash flows generated on attainment desired architecture capability. A discounted cash flow (DCF) model is created as the base case analysis, which is a standard net present value analysis of the project. The NPV is calculated using traditional approach of forecasting revenues and costs, and discounting the net of these revenues and costs at an appropriate risk adjusted rate. Availability of historical data (both primary and secondary data) provides ability to use time–series forecasting. However if such data is not available then management assumptions have to be used. It is important to note that here the project valuation assumes no flexibility and the option pricing solution arrived at in later reduces to the NPV solution in this step if there is no flexibility. This is in

[13] Source: U.S. General Accounting Office (Document GAO-04-394G, April 2004) Version 1.1.

line with the expanded or active NPV definition [Taudes, 1998; Benaroch, 2002].

MODELING UNCERTAINTY

The base case NPV analysis done in the preceding step produces only a single point static estimate. This provides little confidence in the forecasted future cash flows given the associated uncertainties of future events that impact cash flows. Usually the first step in understanding uncertainties is performing a sensitivity analysis on the DCF model. Variables such as revenues, costs, tax rates, discount rates, capital expenditures and depreciation that are part of the base NPV analysis, are changed to see their impact on the NPV, with the intention of understanding the sensitivity of NPV if these variables are changed. The sensitivity analysis categorizes variables into stochastic and deterministic in future. Stochastic variables that impact the NPV are called critical success drivers [Mun, 2002]. As some of these key uncertain variables could be correlated, a correlated Monte Carlo simulation is helpful. Typically correlations can be identified from historical data. Simulations provide a reliable method to approximate these variables' real-life behaviors thereby capturing their uncertainties. In this step organizations must decide whether to treat uncertainties in each variable separately or consolidate all uncertainties into one EA initiative uncertainty. Several advantages over the Black-Scholes Model[14] proposed by Black and Scholes in 1973 make the Binomial Model[15] proposed by Cox, Ross and Rubinstein in 1979 the preferred approach for real options valuations [Copeland and Tufano, 2004]. The binomial model or binomial lattice requires an event tree and a decision tree to be built. An event tree, built in this

[14] The assumptions in the Black-Scholes Model restrict its usage. These assumptions include: *European option, single source of uncertainty, absence of compound options, no payment of dividends, knowledge of market price and stochastic process, constancy in variance* and *knowledge of exercise price*.

[15] So called because in each time period the option value can only go up to one specific value or down to another. It captures contingencies of real options and addresses nearly all of Black-Scholes Model's drawbacks [Copeland and Tufano, 2004].

step, models the set of values that the underlying risky asset may take over time. The main activities involved in building a value-based event tree include:

- Estimating present values (PV) with expected free cash flows;
- Modelling variable uncertainties;
- Generating distribution of PVs using Monte Carlo simulation, and;
- Constructing the PV lattice (the event tree).

IDENTIFICATION AND INCORPORATION OF MANAGERIAL FLEXIBILITY

Strategic options in EA initiatives include options to *defer, explore/pilot, change scale, grow* and *a combination of any two (compound / sequential)*. These options are then used to analyze further details by building decision trees that depict the payoffs from optimal decisions, condition to state of nature. Therefore, the options that are evaluated in this step are the resulting payoffs. Incorporating managerial flexibility allows the investment to analyzed if there is new information. This flexibility however alters the risk characteristics of the EA initiative, thereby resulting in a changed cost of capital [Brach, 2003]. Managing investment risks is perhaps the most crucial justification to incorporate flexibility.

PERFORMING REAL OPTIONS ANALYSIS

The penultimate step in the investment management methodology is to calculate payoffs in the decision tree using either the replicating portfolio approach[16] or risk-neutral probabilities. The analysis must typical consider several investment configurations based on different risk perceptions and associated trade offs. As it is unrealistic to exhaustively consider all configurations, implausible configurations can be excluded using three rules [Benaroch, 2002], which are:

- Consistency between sequences of options in an investment configuration with the sequence in which options materialize in the investment lifecycle.

[16] Used to value real options, it involves creating a portfolio composed of securities whose values are known to have exactly the same payouts as the project in consideration. Typically a

- Ability of options to coexist in an investment configuration.
- Consideration for configurations involving maximal subsets of viable options.

OPTIMIZATION OF PORTFOLIO AND RESOURCES

This step in the methodology is often optional. Certain organizations analyze multiple projects, which are correlated, in a group. In such cases, management also views the results as a portfolio [Ward, 1990]. Embracing a portfolio approach provides organizations to hedge and diversify risks, given the assumption that projects belonging to a portfolio are related on certain parameters. In such an event optimization of the portfolio in addition to the individual projects is crucial.

VII. ENTERPRISE ARCHITECTURE OPTIONS

Application of option pricing theory to generic IT investments have largely focused on evaluating and analyzing such investments that embed a single, a priori known option (such as deferral option, prototype option) [Benaroch, 2002]. Because real options are not inherent in any IT investment, they must be deliberately planned and intentionally embedded in a target IT investment in order to incorporate managerial flexibility and risk control mechanism. As an IT investment (including EA investment) involves multiple risks, there are several potential ways to configure investment paths using series of compound options [Benaroch, 2002].

In order incorporate managerial flexibility in EA initiative investments, it is important to understand the types of risks that an Enterprise Architecture initiative faces. While there is no documented list of specific risks faced during EA development process, analyzing risks in generic IT / IS provide us some insights. IS research has categorized IT risks into those related to IT development [Alter and Ginzberg, 1978; Davis, 1982; McFarlan, 1982; Boehm,

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portfolio of ***m*** shares of the twin security and ***B*** bonds is used to replicate the payouts.

1989] and those arising outside the scope of IT development [Clemons and Weber, 1990; Clemons, 1991; Keen, 1991; Kemerer and Sosa, 1991; Deise et. al., 2000]. Synthesizing literature on IT risks, they can be broadly placed into three categories [Benaroch, 2002]. They are:

- *Organization specific risks* (includes monetary, project, functionality and organizational risks)
- *Competitive risks* (includes risks from competition)
- *Market risks* (includes environmental and systemic risks)
- *Technical Risks* (includes design, implementation, deployment and governance risks)

SUGGESTED ENTERPRISE ARCHITECTURE OPTIONS

In general, IT investments can embed various types of real options, including: *defer, stage, explore, alter operating scale, abandon, lease, outsource* and *growth* [Benaroch, 2002; Kumar, 2002]. However given the nature of Maturity based EA programs all of the above options are not relevant. Table 1 below suggests the relevant *EA Options* that could be embedded in EA investments.

Table 1. Suggested Enterprise Architecture Options

Type of Real Option	Option Elaboration & Investment Features	Conditions for Options to be Viable
DEFER	An option to postpone investment commitment on EA initiative in order to learn more about the potential investment outcomes, expected payoffs and costs. In this scenario an organization may defer the decision to embark on an EA development journey if benefits out of EA are fuzzy and unclear [Benaroch and Kauffman, 2000]. Additionally, this is feasible option when the linkage between EA development objectives and enterprise business objectives are not clear.	• Investment opportunity is not a "now or never" situation • Organization is not exposed to overly competitive environment • Deferral is an explicit decision and not an implicit way to avoid decision • Deferral has the potential to resolve some uncertainties
EXPLORE / PILOT	An option to realize EA implementation on a prototype / pilot scale, which itself has expected payoffs and associated costs. If the pilot is deemed successful, the investment can then be scaled up with a follow up investment that has higher expected payoffs and associated costs [Clemons and Weber, 1990; Kambil, Henderson and Mohsenzadeh, 1993; Erdogmus and Vandergraf, 1999; Kulatilaka et. al., 1999].	• Availability of investment avenues at a reduced scope and cost • Pilot can be performed using existing resources and avoiding full scale investment • Some risks can be mitigated using an exploratory approach • Pilot findings are useful if full scale investment is the next step • Abandoning the pilot has no competitive, operational and regulatory consequences • Pilot should not be performed half heartedly and failure in pilot is seen as learning in

		itself
SCALE UP / DOWN	An option to expand / contract the scope of EA initiative depending on observed conditions [Kulatilaka et. al., 1999]. Changes in operating scope could be achieved by: • Limiting the number of business units / entities where the EA is deployed • Limiting the number of views to the architecture incorporates • Limiting the role and importance of architecture governance	• Possible to enhance / lower investment without much negative consequences to the initiative • Full scale implementation is decomposable into a series of stages that can be performed one at a time and fairly independently • Organization can get benefits of the initiative, albeit reduced, even if full scale implementation is not chosen • Expanding and contracting scale of initiative should have commensurate impact on the investment needs, payoffs and benefits
COMPOUND (SEQUENTIAL)	An option involving two or more of the above options, where the value of an earlier option can be affected by the value of later options or vice versa [Zhu, 1999]. As both EA Maturity Framework [Schekkerman, 2003] and EA Management Maturity Framework [U.S. GENERAL ACCOUNTING OFFICE, 2003] are five level systems, each of the above options is relevant at a particular level. This provides an option to realize EA implementation as a series of sequential implementation stages incrementally without initially committing to attain highest maturity levels.	• Possibility of combining any of the above two options • Phased investment is possible and investment lifecycle can be aligned with the architecture development lifecycle • Benefits of each phase can be clearly delineated and used as an input to decide on investment for the next phase • Not mandatory to commit to all phases upfront, as the investment is contingent upon perceived success of the preceding phase

STRATEGIC (GROWTH)	An option where EA investments provide the capability to create future investment opportunities as well as allow the organization to respond quickly to regulatory and / or competitive threats [Zhu, 1999; Taudes et. al., 2000]. For instance, *Clinger-Cohen Act of 1996* requiring U.S. Federal Agencies to develop and maintain Enterprise Architecture.	• Availability of growth options to take advantage of future opportunities • Capability to make preemptive moves to seize upcoming opportunities, by leveraging on strengths gained from original program

MAPPING ENTERPRISE ARCHITECTURE OPTIONS TO RISKS

Building investment configurations that allow organizations to address EA initiative risks is crucial to the success of the proposed investment analysis and management methodology (see Section VI). This requires mapping of EA initiative risks to options that can be embedded in investment configurations to control them. The proposed *risks-options* mapping is based on the underlying fact that different stages of the investment lifecycle results in different EA initiative risks and only certain options are relevant and valid at different stages of the investment lifecycle. Broadly, the investment lifecycle consists of steps: *genesis, recognition, realization, operation, retirement* and *obsolescence* [Benaroch, 2002]. Table 2 maps the mains sources of EA initiative risks to options that can be used to control them.

VIII. ISSUES AND CHALLENGES

The use of real options to support enterprise architecture development decision-making is an attractive possibility, but it is crucial to understand some of the critical issues and challenges in adopting this approach, specially for organizations who have no or limited prior experience with real options based investment analysis and decision making and elementary investment management practices. These issues, elaborated in subsequent sections, are categorized into:

ISSUES RELATED TO REAL OPTIONS / OPTIONS PRICING THEORY

The value of an option is determined by several variables [Copeland and Antikarov, 2001] that include: (1) current value of the underlying asset, (2) variance in the value of the underlying asset, (3) dividends paid on the underlying asset, (4) exercise price of the option, (5) time to option expiration and (6) risk free interest rate corresponding to life of options. In case of real options, the underlying assets are not financially traded but projects. Therefore applying OPMs in these situations need careful treatment, and issues arising include:

Table 2. Mapping of EA Risk Factors to EA Options

Risk Category	Risk Factor	Options				
		Defer	Explore	Scale up	Scale Down	Grow
ORGANIZATION SPECIFIC RISKS	Organization cannot afford EA initiative	+	+			
	Actual benefits may be less that planned benefits	+	+	+	+	+
	Lack of relevant skills in staffs	+	+		+	
	Project is too large and / or complex		+			
	Inadequate infrastructure for implementation		+		+	
	EA goals not aligned with business goals		+			
	Internal politics and non cooperation	+	+		+	
	Change management	+	+			
	Absence of architecture governance practices	+			+	
	Slow diffusion of process ideas		+		+	
	Lack of senior management commitment to EA development	+	+		+	
COMPETITIVE RISKS	Lack of comparative advantage	+			+	
	Smarter and nimble competition	+	+			
MARKET RISKS	Unanticipated action of regulatory bodies	+				
	Environment changed requirements	+	+			
	Vendor stability	+			+	
TECHNICAL RISKS	Modification of EA reference architectures	+	+			
	Introduction of superior standards		+	+		+
	Inadequate business process management		+			
	Use of proprietary standards		+			
	Use of immature technologies and products	+	+		+	
	Absence of solution building blocks	+	+		+	
	Lack of traceability in solutions continuum				+	

- *Knowledge of Current Asset Value*: Assessing the value of EA initiatives is imprecise and still evolving. This difficulty stems from the fact that benefits of

EA are largely intangible and extended over time, besides its success be qualitative in nature [Bernus et. al., 2003]. While there is evidence that EA maturity is positively related to IT / IS performance [Perks and Beveridge, 2003], difficulties in estimating EA initiatives will remain a serious impediment to accurate valuation of some EA Options.

- *Continuity to the Price of Asset*: The Black-Scholes OPM assumes that the underlying asset's price process is continuous. This assumption is routinely violated by real options, thus underestimating the value of deep out-of-pocket-money options.
- *Knowledge of Variance and its Assumed Constancy*: Given the multi year extended time frames of EA initiatives, the estimation of variance of the underlying asset is challenging, further exacerbated by the definite violation of the assumption that it would remain constant during the course of the program. Changes in variance need to be explicitly modeled into real options.

ISSUES RELATED TO INVESTMENT MANAGEMENT PRACTICES

A comprehensive IT investment analysis and management framework has the potential to provide impetus to embracing more contemporary analyses approaches. U.S. General Accounting Office has specified a comprehensive IT investment analysis and management framework [U.S. General Accounting Office, 2004]. This categorizes IT investment into five stages of maturity[17]. Each stage consists of critical processes that are crucial to that specific stage and each critical process contains a set of key practices (tasks) that must be performed by an organization in order to implement and institutionalize the critical practices [U.S. General Accounting Office, 2004]. Figure 8 depicts the five stages and IT investment management maturity.

[17] Partly derived from SEI's *Software Acquisition Capability Maturity Model*

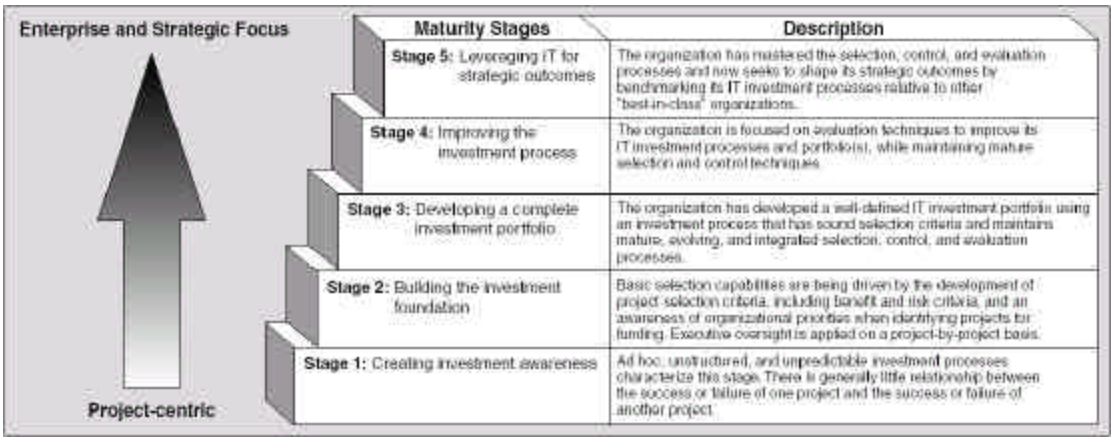

Figure 8. Stages of IT Investment Management Maturity[18]

Some major issues and challenges that organizations are likely to face are:

- *IT Investment Management Maturity*: Adopting a real options based approach to investment analysis necessitates a paradigm shift where corporate valuation may no longer depend on traditional fundamentals but rather on future expectations. Real options are a new way of thinking rather than mere application of advanced analytical methods. As seen in Figure 8, an organization moves up the investment maturity framework in a phased and gradual manner. Evidently, organizations already at the upper reaches of the maturity stages are more likely to embrace the proposed new approach. Hence it might be beneficial for managers to assess their investment maturity before exploring the adoption of real options based framework in the context of EA initiatives.
- *Alignment to Investment Management Lifecycle*: It is critical for organizations to recognize the fact that when analyzing EA investments, alignment of the Architecture Development Methodology to the investment lifecycle is imperative to create and build viable EA options that can be analyzed and embedded within IT investments. The investment lifecycle typically consists of the following stages [Benaroch, 2002]:
  - *Inception*: Most likely facilitated by earlier investments, investment opportunity exists.

[18] Source: U.S. General Accounting Office (Document GAO-04-394G, April 2004) Version 1.1.

- *Recognition*: Investment is perceived as a viable opportunity to be exploited.
- *Building*: Investment decision is made and the opportunity is realized.
- *Operation*: Investment is in operation producing direct and measurable payoffs, which can be compared against planned payoffs.
- *Retirement*: Investment, while still in operation, continues to produce in direct payoffs, including new investment opportunities and a possibility of initiating new investment cycles.
- *Obsolescence*: Investment has served its purpose of providing both direct and indirect benefits. Assets and capabilities yielded by the investment become obsolete.

ISSUES RELATED TO ENTERPRISE ARCHITECTURE DEVELOPMENT

The primary purpose of an EA is to 'inform, guide and constrain the decisions for the enterprise, especially those related to IT investments' [CIO Council, 2001]. Essential reasons for developing an EA include [CIO Council, 2001]:

- *Alignment*: Ensuring that the enterprise operates in a way that is aligned with the management's intent.
- *Integration*: Connectivity and interoperability is managed across the value chain.
- *Change*: Facilitating and managing change to any aspect of enterprise, supported by full visibility and transparency.
- *Time-to-market*: Reducing systems development and application generation timeframes.
- *Convergence*: Striving towards a standard IT product portfolio as in the Technical Reference Model (TRM).

As is evident from the paragraph above, the critical driver for an EA initiative is to control and manage IT investments. Value enhancement is seldom mentioned explicitly as one of the primary goals of an EA. The shift from controlling IT investments to enhancement of organizational value can be a large one for many organizations, often requiring a change in the mindset. The shift is made more challenging by the following factors, that ultimate influences an organization's ability to adopt the real options based approach.

- *Quantifying costs, benefits, risks and uncertainties*: The most frequently cited benefits of EA include: *enterprise licenses, improved systems interoperability, enhanced organization and change management, enhanced productivity* and *lower systems costs* [Hite, 2003]. While EA benefits, risks and uncertainties are available in limited form, these still are extremely qualitative and subjective in nature. This creates obstacles for organizations attempting to adopt real options based approach.
- *Role of Managerial Flexibility*: While the benefits of managerial flexibility is

reason enough for its incorporation, organizations deciding to invest in an EA initiative, usually consider it as a full scale investment with little scope for investment flexibility midway during the program. Organizations largely depend on two extreme positions, i.e. to abandon the program if benefits are way below expectations or to continue full steam ahead otherwise. Part of this behavior can be explained by the fact that the underlying reason for some (if not all) organizations aiming for EA have a short term goal to have a documented enterprise architecture to meet regulatory requirements (like the Clinger-Cohen Act [1996]), rather than to earnestly utilize to either control and manage IT investments or enhance organizational value. For instance, in a study conducted by the U.S. General Accounting Office, between 2001 and 2003, the average EA maturity within U.S. Federal Agencies moved from 1.74 to just 1.76, with over ¾ of the agencies actually remaining at the same EA maturity level or dropping to lower maturity levels [Hite, 2003].

- *Factors for Evaluation*: Evaluating EA initiatives include several factors besides required investment. These could be derived from program benefits, risks and uncertainties. In order to improve investment decisions, researchers and practitioners have been advocating the use of fuller set of factors [Primrose, 1991; Sarkis and Lin, 1994]. This calls for using multi criteria decision-making techniques that includes: analytical hierarchy process, data envelopment analysis, goal programming, multi-attribute utility theory and simulation [Chandler, 1982; Suresh and Meredith, 1985; Kleindorfer and Partovi, 1990; Stam and Kuula, 1991; Suresh and Kaparthi, 1992; Pandey and Kengpol, 1995; Khouja, 1995]. Use of multi-objective multi-criteria methods as cited above facilitate evaluation of intangible benefits of complex projects like EA development which attempts to meet the needs of numerous users / user groups [CIO Council, 2001].

SUGGESTIONS FOR FURTHER RESEARCH

Some of the plausible areas for further research include addressing some of the

identified issues like *factors influencing adoption of ROA over traditional NPV analysis for EA investments, role of IT investment management maturity on EA investment decisions, identifying and assessing the impact of EA program uncertainties, crafting innovative options like rainbow options, understanding the criticality of conversion contingencies in narrowing the gap between potential and realized value* and *identifying the extent of managerial flexibility required to make optimum decisions in exercising options*. Future research in these areas will not only enrich the understanding of EA related investments but also along with the contributions of this paper, provide enough impetus to develop comprehensive investment management guidelines potentially to improve its success rate.

IX. CONCLUDING REMARKS

Effective use of enterprise architectures is a recognized strength of successful enterprises. Metaphorically, an EA is to an organization's operations and systems as a set of blueprints is to a building. EA provides a clear and comprehensive view of the structure and operations of the organization. This paper presented a real options based approach to view investments in EA. This approach stresses that EA initiatives have several associated uncertainties impacting the benefits derived, i.e. substantial portion of the benefits are derived from implementation opportunities. In contrast to traditional DCF based methods, where uncertainty of possible future implementation opportunities are penalized, the proposed approach actually acknowledges the existence of risks and uncertainties and allows investments to be configured accordingly. Incorporating managerial flexibility involves understanding and acknowledging the existence of temporal aspects in the investment cycle. This allows managers to build investment configurations that suit their organizations and implementation scenario. However adopting real options based approach has several implications on organizational business and investment management practices. They include:

- Enterprises are (largely) open to implementing EA initiatives in a staged manner, with clear benefits, payoffs, risks and uncertainties identified at each stage. A staged approach to architecture development and implementation clearly delineates the fact the organization expects and values information that becomes available during the course of implementation.
- Enterprises consider investment analysis and management as a strategic business practice and not an 'academic' exercise with no bearing on the business. A real options based budgeting process is an extremely dynamic approach requiring continuous and close monitoring of both internal as well as external value and uncertainty drivers. A great deal of organizational discipline is mandatory as exercising the options at the right time is equally important as identifying the right ones.
- Enterprise architecture initiatives are funded to improve the organization's overall Return on IT Investment and allow balanced and reasoned growth of its IT infrastructure. This also means an architecture-based approach to IS / IT is seen as a desirable and valuable activity in the long term.
- Enterprises recognize that architecture based approach to IS / IT development is neither a 'quick fix' nor an 'inexpensive' solution, hence requires serious investment analysis and expected payoffs. In addition, the EA initiative is value driven and not cost driven.
- Enterprises are able to identify 'viable options' that can be embedded within investment to craft innovative investment configurations. Organizational culture has significant impact as to what is recognized as a real option. Two organizations in the same industry and exposed to the same exogenous uncertainties may easily come to opposite conclusions as to what uncertainty means for their business. For instance, one software services organization might view EA as a 'necessary evil' while another may consider it as a 'leveler' allowing it to compete with larger service providers.
- Organizations are willing to utilize the options mindset to structure

relationships with different stakeholders like partners, customers, suppliers and shareholders.

The importance of *EA Options* is driven by the fact that, typically, the rationale for such initiatives is 'the eroding status quo', that is, within the current business environment options are not economically justified, but when conditions change, for instance, a regulation (or a business practice) requiring all IS / IT entities to have minimum architecture maturity level, they can bring several benefits, including being an important differentiator. As the value of *EA options* becomes obvious to competitors inducing them to exercise their options, the value of such options can witness large erosion. Hence in such a scenario it is important for organizations to act early, thus avoiding loss of valuable opportunities if the value of options from active management is undervalued or neglected.

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LIST OF ACRONYMS

ABB	Architecture Building Block
ADM	Architecture Development Methodology
ARIS	Architecture for Information Systems
BSC	Balanced Scorecard
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CE	Core Element
CIMOSA	Computer Integrated Manufacturing Open Systems Architecture
CSA	Critical Success Attribute
DCF	Discounted Cash Flow
EA	Enterprise Architecture
EAMM	Enterprise Architecture Management Maturity
EAMMF	Enterprise Architecture Management Maturity Framework
EE	Enterprise Engineering
EEM	Enterprise Engineering Methodology
EI	Enterprise Integration
FEAF	Federal Enterprise Architecture Framework
GERAM	Generalized Enterprise Reference Architecture and Framework
GRAI / GIM	Graphs with Results and Activities Interrelated / Integrated Methodology
IFAC	International Federation of Automatic Control
IFIP	International Federation of Information Processing
IRR	Internal Rate of Return
NPV	Net Present Value
OPM	Options Pricing Model

PEM	Partial Enterprise Model
PERA	Purdue Enterprise Reference Architecture
PV	Present Value
ROA	Return on Asset
ROI	Return on Investment
SBB	Solutions Building Block
SWOT	Strength, Weakness, Opportunity and Threat
TCO	Total Cost of Ownership
TOGAF	The Open Group Architecture Framework
TRM	Technical Reference Model
U.S.GAO	United States General Accounting Office

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