SUMMARY

Massachusetts Institute of Technology

ENTERPRISE DYNAMICS
Architecture-Based, Decision-Driven Approach

A Collaborative MITRE-MIT Research Project

(MIT Project #6898894)

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Overview

The MITRE-MIT Collaborative Project on Enterprise Dynamics was initiated on October 1, 2006. The MITRE Principal Investigator for the project is Dr. Kenneth Hoffman. The MIT Principal Investigator is Dr. Kirkor Bozdogan, with Prof. Joseph Sussman serving as the MIT Co-Principal Investigator. The purpose of the project has been to develop concepts, models and tools for managing enterprise complexity and dynamics in an emerging network-centric age. More specifically, the project has focused on computational enterprise modeling and simulation for designing and evolving "next generation" enterprises that are flexible, adaptive and robust (FAR). The project has stressed the development of a "proof-of-concept" enterprise modeling and simulation capability, to contribute towards the creation of complex enterprise systems architecting and engineering as a new field of inquiry and practice. Overall, the project has provided substantial mutual benefits to both MIT and MITRE.

The project has involved many knowledge exchange events between MIT and MITRE researchers. In particular, two annual Enterprise Modeling Exchange events have been held (on January 11-12, 2007 and September 25-26, 2008), bringing together MIT and MITRE researchers actively engaged in various aspects of computational enterprise modeling and simulation for enterprise transformation. The agenda, and an extended summary, of the first event have already been made available to MITRE researchers. The agenda for the second event is attached. A bound copy of all the papers presented at the second event has also been made available to MITRE researchers.

The project has provided funding for the doctoral research of an MIT graduate student, Christopher Glazner, who has subsequently joined MITRE as an employee. His doctoral thesis is entitled "Understanding Enterprise Dynamics Using Hybrid Modeling of Enterprise Architecture." The thesis, upon completion soon, will be made available to MITRE in partial fulfillment of the project's objectives. In addition, the project has provided synergistic benefits to MITRE researchers by serving as a conduit to a spectrum of MIT-based research activities, particularly those pursued under the aegis of the Lean Advancement Initiative (LAI) in such areas as systems engineering, enterprise architecting, and enterprise modeling and design.

An example of these synergistic benefits is the presentation made by Prof. Joseph Sussman at the September 25-26 MITRE-MIT Enterprise Modeling Exchange, which provided an overview of two recent MIT ESD doctoral theses supervised by Prof. Sussman: "Increasing Value of a Family of Products through Flexibility: Hedging Against Uncertainty" (by Joshua McConnell, completed May 2007) and "Symbiotic Strategies in Enterprise Ecology: Modeling Commercial Aviation as an Enterprise of Enterprises" (by Sgouris Sgouridis, completed August 2007).

Finally, an important outcome of the collaboration between MIT and MITRE researchers, started under the auspices of this project but considered as a separate effort, is expected to be a forthcoming book, Complex Enterprise Systems Modeling and Engineering for Operational Excellence (Dr. Kenneth Hoffman [MITRE] and Dr. Kirkor Bozdogan [MIT], Co-editors.

A condensed summary of the presentation made by Dr. Kirkor Bozdogan at the September 25-26 MITRE-MIT Enterprise Modeling Exchange, based on the research supported in part through the Enterprise Dynamics project, is provided below. A copy of the presentation is attached.

Modeling-Enabled Design of Enterprise Transformation: Implications for Complex Enterprise Systems Architecting and Engineering

Introduction

The main problem motivating the paper is the failure of most enterprise transformation efforts, which has been pointed out by a growing number of observers. To be sure, the failure of many enterprise transformation efforts has multiple root causes, as already documented in the literature. It is posited, as a going-in proposition in this paper, that failing to address effectively enterprise complexity and behavioral dynamics – conceptually, methodologically, practically -- is a systemic source of the failure of many enterprise transformation efforts. This then begs the question, "how well do our concepts and tools address enterprise complexity and dynamics?" This question is addressed by concentrating on two salient approaches. The first is systems engineering, which has been expanded in recent years, beyond its traditional domain of designing and developing complex engineering systems, to address the performance improvement and modernization challenges facing complex socio-technical systems. The second is represented by the planned change approach to transforming enterprises. It is pointed out that systems engineering has fundamental limitations beyond certain threshold complexity levels. Meanwhile, it is shown that the planned change model has come into growing disfavor because of its basic conceptual and practical weaknesses.

The paper thus argues that there is an urgent need to develop new concepts, tools and methods capable of dealing effectively with enterprise complexity and dynamics in order to design and implement successful enterprise transformation. Consequently, the paper's focus is on the modeling-enabled design of the "fuzzy-front-end" enterprise transformation process, emphasizing "designing the design process" in the hope of addressing the larger problem of "poor planning" often leading to the failure of enterprise transformation efforts. The expectation is to provide a theory-grounded design process to help increase the likelihood of success in achieving enterprise transformation. Particular emphasis is placed on the role and application of computational enterprise modeling and simulation in designing the transformation process. An important expectation is to provide a unified theoretical perspective by integrating knowledge from many fields, which currently remain highly fragmented and inaccessible. Another expectation is to explore modeling strategies under multiple contingency conditions to examine the ramifications of specific high-level enterprise design issues and decisions.

Conceptual and Methodological Issues

In order to make progress in this area, however, a number of conceptual and methodological issues must first be addressed. An immediate question, for example, concerns how to define and conceptualize enterprises. Another question pertains to how to think about enterprise transformation, focusing on theories of enterprise change and transformation as well as on the nature, scope, dimensions and processes of enterprise transformation. A third question relates to how to achieve enterprise transformation *by design.* A still another question concerns how best to map out the topology (state-space configuration or environment) defining future contingency conditions facing enterprises, recognizing that transformation efforts must deal effectively with issues of risk, uncertainty and ambiguity. Finally, an important question, central to the paper, concerns the role of computational enterprise modeling and simulation in designing the enterprise transformation process.

A few organizing ideas are next presented to communicate quickly and efficiently the logic flow pursued in the paper. The starting point is the observation that many natural and human-made (e.g., socio-technical) systems can be characterized as *complex adaptive systems* that have an underlying design (architecture) that can be discovered, analyzed and understood. "Real-world" enterprises (public, private), which can be viewed as goal-directed (purposeful) socio-technical systems, represent an important class of *complex adaptive systems*. Hence, "real-world" enterprises, too, have an underlying design (architecture) that can be discovered, analyzed and understood. *Enterprise architecture model* is an abstract holistic representation of an enterprise's underlying design (architecture) that can be captured by employing *computational enterprise modeling and simulation*. Finally, enterprise architecture model can serve as an "analytical engine" to support *enterprise architecture design* decisions to transform the existing enterprise architecture design.

These ideas are further explained and refined with reference to the extant literature on the evolution of systems thinking on enterprises. The main takeaway from this discussion is that holistic, not reductionist, thinking is needed in thinking about and transforming modern enterprises as *complex adaptive systems*.

Enterprises, as complex adaptive systems, are defined as goal-directed (purposeful) socio-technical systems sharing a common purpose to create value for their multiple stakeholders by performing their defined missions, functions or businesses. Enterprises comprise networked entities spanning multiple organizational units (e.g., program enterprises), divisions or subunits of companies (organizations), multi-divisional companies, government agencies or departments.

Next, theoretical perspectives on enterprise transformation are reviewed. The dominant academic view, until recently, has been the "punctuated equilibrium" model of organizational change, which argues that relatively long periods of incremental change (called convergent periods) are sharply disrupted by short periods of discontinuous, radical change (reorientation periods) caused by major environmental change. Over the convergent (stable, equilibrium) periods, change is rare, risky, ill-advised and often made very difficult by organizational (structural) inertia. Radical change following environmental jolts is drastic, affecting an organization's basic structure, configuration, and patterns of activity.

Emerging (new) consensus view is that organizations change continuously in adaptive response to shifts in their external environment. That is, change is frequent, relentless, often rapid and rather common. The ability of organizations to change is a core capability for survival and success. Change is driven by continued attention to the present and future: transitions provide direction and continuity, set the tempo, and shape time-based evolution. This emerging view is pretty much in tune with the theory of complex adaptive systems. The major takeaway is that enterprise transformation should not be viewed as a short or long jump from a given "current-state" to a defined "future-state" but rather as a continuous, dynamic change process in response to an unfolding external environment. More precisely, from the perspective of the theory of complex adaptive systems, enterprise transformation should be viewed as a multilevel co-evolutionary process, wherein enterprises search, adapt and learn in a shifting and complex landscape. Landscape complexity depends on the intensity of the web of multilevel interdependencies. The main challenge is how to avoid the catastrophe of getting stuck in local pockets. The task of the enterprise change and transformation process is for the management to "tune" the enterprise's internal and external interdependencies, as the enterprise is engaged in a process of dynamic change with two-way causation connecting the enterprise to its evolving environment.

Another conceptual issue requiring attention is the sharp distinction to be drawn between *design* and *science*, which is often blurred or confused, much to the confusion and detriment of those engaged in either design or scientific inquiry or in both. Design marks the principal difference between the professions and the sciences, as Herbert Simon has already pointed out (Simon 1962). The dominant role model for design is architecture or engineering. The basic orientation of design is a heavy emphasis on future-oriented "solution-finding"; it is concerned with systems that do not yet exist in reality. Its value system is driven by "will it work", not by "what is true." It seeks to attain the best solution available for the unique problem at hand, given the constraints. Its mode of thinking is normative, stressing synthesis. It is pragmatic, placing heavy emphasis on heuristics or best practices; it draws on *design causality*, which rests on knowledge that leads to action and can be validated. It relies on intuition and creativity, involving practical experimentation and tinkering.

The basic orientation of science, on the other hand, is to develop an understanding of existing phenomena, by discovering and analyzing existing objects or circumstances. The role model of science is the natural sciences. Its value system is disinterestedness and consensual objectivity. Its mode of thinking is analytical, not normative. The nature of knowledge in science is representational, both descriptive and explanatory, of the world as it is rather than as it should be or might be. Its methodology is the scientific method, involving controlled experimentation and hypothesis testing, which may involve, for example, computer simulation to understand cause-effect relationships.

This distinction between design and science is very important for the simple reason that, just as it is unimaginable to have engineering without the scientific base supporting it, it is equally unimaginable to design the architecture of future enterprises without a scientific knowledge base supporting it. Thus, the basic import of this discussion is that designing the transformation of complex enterprises must reflect design propositions guided by theory-grounded principles. A strong implication of this observation for the future is that the design of modeling-enabled, architecture-based, and decision-driven enterprise transformation efforts must be guided to a substantially larger degree by a growing body of scientific knowledge governing the structure and dynamics of enterprises as complex adaptive socio-technical systems.

Enterprise Transformation by Design: Proposed Conceptual Framework

The paper next presents a critical discussion of the current general approach to proactive enterprise transformation, points out its essential weaknesses, and argues, based a careful review of the emerging literature on organizational change and transformation, that a whole new approach must be taken to designing the enterprise transformation process. The proposed conceptual framework consists of a feedback-looped process of enterprise change, adaptation and learning *by design*. The proposed framework is fully consistent with the growing consensus in the literature that suggests a basic shift in emphasis away from a rational, planned, enterprise change process to one of *guiding* the change process.

This has several implications for the process of future enterprise architecture design and its implementation to achieve enterprise transformation. It means, for example, considering organizational design as "virtual adaptation." It also means moving from *design* to *designing* as an an-going process. It further means learning to design organizations and learning from designing them. Strongly implicit in these statements is the notion that organizations should be designed for change and that, moreover, the task involves designing organizations that design their environments. As it is pointed out in the paper, however, the task of designing the enterprise transformation process must take into explicit account the enterprise's evolving fitness landscape as well as the time-scale chosen for the intended transformation. It remains difficult to offer prescriptive guidelines without consideration of the multiple contingency configurations under which the enterprise can be expected to operate.

The framework encompasses four major building blocks – discover, design, implement, and sustain – in moving the current enterprise architecture from the present state to a desired future state. The proposed framework involves an *inner loop learning and action* cycle, indicating thinking and action within the confines of the current or existing frame of reference, as well as an *outer loop learning and action cycle*, indicating learning and action outside the current framework or paradigm concerning the enterprise. The enterprise's interactions with the changing external environment are explicitly considered, under the argument that ,both the enterprise and its environment interact continuously, at multiple scales, as both co-evolve over time.

The framework's four major building blocks are next examined in greater resolution, progressively, to draw attention to the critical role played by enterprise modeling and simulation, not only to evaluate the current enterprise architecture but also to help generate a family of internally consistent future state enterprise architecture solution options. These options are evaluated, the "best" architecture solution option is selected, and the selected option is used as the major analytical input into the design of the desired future-state enterprise architecture. The future-state enterprise architecture is viewed both as a "system" design (at the strategic enterprise-wide level) and as "detailed design" at the tactical and operational level.

The term *enterprise architecture design* is used to refer to the strategic system-level design. The term *enterprise engineering design* is used to refer to the tactical and operational architecture and engineering of the enterprise, also encompassing the design of the enterprise's executable business and information systems architecture and engineering. In general, the level of detail encompassed within the proposed framework is seen to vary depending on the time scale for the intended enterprise change and transformation process, where the level of multiscale resolution would be greater in the near-term time scale but less so for outer years. The proposed framework envisions a rolling process to allow for continuous learning and adaptation, as the enterprise pursues deliberate change and transformation over time *by design.*

The framework further defines, as part of the design process, the development of the strategic implementation plan, as well as the detailed implementation roadmap, before moving on to the implementation cycle. Both the major building blocks, and the specific detailed action steps that are defined within each, constitute a comprehensive roadmap to guide future enterprise transformation efforts. In the proposed framework, enterprise architecture design is akin to "system" engineering design in product development.

Role of Computational Enterprise Modeling and Simulation

Computational enterprise architecture modeling and simulation plays a critical role in the proposed framework in several ways. Most importantly, it enables a formal high-level abstract "causal" representation of an enterprise's architecture, by providing a theory-based "holistic" view and a systematic framework allowing a simultaneous consideration of multiple time-scales of change, multiple contingency conditions facing the enterprise, and a multitude of design variables. The modeling and simulation approach thus provides a computational platform for (a) evaluating the defined current-state architecture, (b) defining desired future-state enterprise architecture options, (c) conducting virtual real-time interactive "what-if" experiments to evaluate the impact of interdependent decision choices in order to anticipate future outcomes, reduce complexity, and manage uncertainty.

Moreover, the modeling and simulation approach serves a number of practical purposes. For example, it provides a "big picture" view of the enterprise and its evolutionary dynamics, in addition to serving as a descriptive as well as a prescriptive tool to motivate and guide enterprise change. It also provides an educational function for all stakeholders. It further serves as a very important explanatory function, by generating new insight into critical relationships and behavioral dynamics characterizing the enterprise. Finally, it can serve as a "serious gaming" tool by providing an interactive "what-if" analytical capability to evaluate alternative decision options. In summary, computational enterprise architecture modeling and simulation harnesses the power of modern modeling and simulation "technology" to help enterprise managers make informed decisions.

Computational enterprise modeling and simulation has come of age especially during the past decade or so. The various modeling approaches that have been employed most often encompass systems dynamics, agent-based modeling, NK modeling of evolving enterprise fitness landscapes with its origin in evolutionary biology, multidisciplinary design optimization, and other modeling approaches (e.g., network analysis, genetic algorithms, neural networks, optimal control). Quite often, models discussed in the academic literature can be viewed as "toy" models to explore general theoretical propositions. However, increasingly these models, singly or in combination, are being utilized to address serious enterprise-level strategic and operational questions.

In general, however, there is no such thing as an all-purpose enterprise (or enterprise architecture) model. It is, therefore, necessary to define the specific context (change regime), design objectives, and change strategies for best model selection and application. Accordingly, the paper provides guidance in the selection and application of specific models, as well as combinations of models, as a function of the enterprise's contingency-based contexts (change regimes), dominant ("bull's eye") design objectives requiring the greatest focus under the various identified specific contingency conditions, salient change strategies requiring the greatest attention to achieve the target design objectives, and the appropriate modeling approaches for addressing the identified design targets and change strategies. Thus, the guidance provided by the paper considers, concurrently, multiple contingency conditions driving the specific expected change regimes, desired design targets, needed change strategies, and model selection. This, in itself, represents an important contribution made by the paper.

Exploration of Multiple Enterprise Contingency Configurations Driving Model Selection and Application

To demonstrate how the proposed conceptual framework for modeling-enabled design of the enterprise transformation process can actually be utilized the paper next explores the enterprise's competitive fitness landscape by employing NK modeling. In this model, the enterprise's fitness landscape topology is seen as being either relatively stable (smooth), indicating a lower density of internal and external interactions, and relatively unstable (or rugged), indicating a very high density of internal and external interactions. The enterprise's environment is conceptualized as having two layers: (a) the direct environment defining its "task environment", encompassing customers, suppliers, and competitors directly interacting with the enterprise and whose behavior can (might) be influenced or controlled by the enterprise, and (b) the general environment, encompassing technology, markets, economy, and regulatory, institutional, social factors, which remain outside the influence or control of the enterprise.

A fairly simple interpretation of the results is to consider that the environment is relatively stable or relatively unstable. The relatively stable environment can be seen as one where the rate of change is relatively slow in the respective agents, entities or factors within the enterprise's direct environment as well as within its larger or general environment. The relatively unstable environment can be characterized as fast-paced changes in the enterprise's direct as well as general environment (e.g., hyper-turbulent markets, fast-changing technology, unsettled institutional or policy environment). Further, the time scale for anticipated enterprise change is defined (e.g., near-term, longer-term).

Before proceeding further with a thought experiment to illustrate the definition of multiple state (time-related) and space (environment–related) contingency conditions are their ramifications for modeling-enabled design of the enterprise transformation process, the paper provides an overview of enterprise change strategies. Two basic change strategies are highlighted: *planned change* and *emergent change*. Other proposed, lesser known, change strategies are deferred for the time being. *Planned change* refers to a lockstep, linear, sequential approach that is control oriented. The planned change model defines the current-state, defines an objective (future-state) in advance, and adopts a prescriptive approach, where strategic analysis, strategy development, and strategy implementation are linked together sequentially. The planned change model is found to have fundamental theoretical and practical flaws. To remedy the various theoretical and practical shortcomings of the planned change model, the *mosaic change* model has been proposed in recent years. The *mosaic* change (transformation) approach proposes to introduce a sequence of planned change initiatives focusing on discrete enterprise functional or process areas, which would allow for managing interfaces to prevent resistance to change stemming from boundary disputes.

In contrast with the planned change model, the *emergent change* model refers to change strategies where the resulting patterns are those that were not expressly intended and where a set of actions that are put into motion converge in time in some sort of consistency of pattern. Emergent change is a continuous, open-ended process of adaptation to changing conditions. It is characterized by trial, experimentation and discussion. It emphasizes interpretation, organizational learning, and adaptation. The emergent change model is also consistent with the complexity theory perspective: it represents a non-equilibrium approach to enterprise change, as an approach to "managing the unknowable" through organizational learning, developing flexible structures, and "accepting the resulting anxiety."

With this quick tutorial on planned vs. emergent change strategies, a simple thought experiment can now be outlined in the form of a simple two-by two contingency matrix that can be used to depict both the time scale for intended enterprise change *and* the topology of the enterprise's fitness landscape. Thus, for example, the southwestern quadrant (near-term time scale, relatively stable environment) depicts a relatively smooth topology defining an *incremental change* regime. For an enterprise finding itself in such an environment (state-space contingency configuration), the dominant enterprise architecture design target would seem to be seeking greater *efficiency*. Such an environment would seem ideal for pursuing a modified planned change strategy (e.g., *mosaic* change).

The *mosaic* change (transformation) approach, offered to overcome the various theoretical and practical shortcomings of the planned change model, proposes to introduce a sequence of planned change initiatives focusing on discrete enterprise functional or process areas, which would allow for managing interfaces to prevent resistance to change stemming from boundary disputes. Such a strategic change approach can make effective use of lean thinking, six sigma and related continuous enterprise change strategies to achieve greater enterprise-wide efficiency. Relatively heavier emphasis in pursuing the various change initiatives would be placed on "tuning" the enterprise's internal interactions, for instance to improve enterprise integration and continuous process improvement. Consequently, in search of greater efficiency, the enterprise would select such modeling approaches as system dynamics, agent-based modeling, discrete event simulation, Petri nets modeling focusing on workflow processes, and Boolean networks modeling focusing on enterprise interactions, or a combination of these models.

Other state-space contingency configurations can be similarly defined and their implications for the expected prevalent change regimes, dominant enterprise design targets, change strategies to achieve the desired design targets, and modeling choices most closely supportive of the intended change process can be spelled out. The northwestern quadrant (change context) defined by a longer-term time scale *and* a relatively stable environment would thus suggest a change regime calling for steady, sustaining, change process to achieve stable growth through greater efficiency and effectiveness. The main design target in this quadrant would be *sustainability*, which can be attained by pursuing a similarly modified planned change process (e.g., mosaic change), stressing improved alignment of the enterprise's entire value stream, among other things. In such a change context, modified planned change (e.g., mosaic change) might be effectively pursued. Heavy emphasis would be placed on "tuning" both internal and external interactions, not only to do things right but also to do the right things. In such a change context, for example, linked system dynamics and evolutionary multi-objective optimization (e.g., in designing product platforms) models might be stressed to good advantage.

Now focusing on the northeastern quadrant defined by the longer-term change time-scale and a relatively unstable environment, the main change regime would appear to be seeking on-going fitness in order to survive and succeed. In such a change context, the favored enterprise architecture design target would be *adaptability,* with relatively heavier emphasis on "tuning" the enterprise's external interactions in order to manage risk and uncertainty in a fast-changing and ambiguous environment. The enterprise would thus adopt an emergent change strategy, aimed at achieving improved adaptability. Accordingly, model selection would concentrate on a combination of NK modeling, network analysis, agent based modeling, and complex real options modeling in order to anticipate and deal with emergent behavior in a fast-response environment.

Finally, the southeastern quadrant defined by a near-term change time scale and a relatively unstable environment defines a fast-evolving change regime, where the favored enterprise architecture design target would be to achieve greater *flexibility*. In order to achieve greater flexibility, the enterprise would adopt an emergent change strategy, placing central emphasis on "tuning" both internal and external interactions. It would need to adopt new business models stressing networked collaborative relationships, develop the requisite "sense and respond" capabilities, adopt a "trauma-center-like" fast coordination methods, achieve improved information-technology-enabled closely-knit responsive relationships across its value stream, and, in general, strive to evolve designed-in enterprise-wide flexibility. Modeling choices in such an environment would concentrate on some combination of NK modeling, agent-based modeling, and network analysis (e.g., to anticipate and guard against unanticipated supply chain disruptions).

Principal Findings

Several important findings of the paper can be summarized as follows.

First, the proposed conceptual framework provides a unified theoretical and methodological platform, as well as a practical roadmap, by bringing together integrated insights from systems science, complexity theory, engineering systems, and organization theory (and, more broadly, from the social sciences). The proposed framework can serve as a solid foundation for advancing complex enterprise systems architecting and engineering, for several reasons.

(1) It focuses on enterprises as systems, rather than on systems used by or within enterprises (e.g., collection of information-technology-driven applications, such as enterprise resource planning (ERP), supply chain management (SCM), product data management or product lifecycle management (PDM/PLM), customer relationships management (CRM), knowledge management and collaborative tools to improve enterprise integration and improve business processes). Thus, the proposed framework provides a strategic "front-end" driver for much of what in recent years has come be lumped together under the title of enterprise architecture reference frameworks and applications.
(2) It places explicit emphasis on enterprise complexity and dynamics, by viewing enterprises as purposeful complex adaptive systems exhibiting nonlinear interactions, high degree of interdependence, dynamic change, adaptive behavior, emergence properties, and self-organization. It employs the construct of enterprise architecture, as a dynamic concept, to help understand, capture and alter the underlying complexity and evolutionary trajectory of enterprises.
(3) It stresses holistic systems thinking and action, by employing computational enterprise architecture modeling and simulation as a central "analytical engine" to help define and evaluate current-state enterprise architecture, define and evaluate future-state architecture options, and to help design the desired future state enterprise architecture. This is in sharp contrast with the essentially reductionist thinking exhibited by many conventional methods, such as systems engineering. Another example is the "multi-view" perspective espoused by the enterprise architecture reference frameworks that are primarily concerned with the integration of information system architectures and enterprise business process architectures. Neither approach presents a theory-grounded methodology in support of the practice of structured decomposition in addressing complex systems, which are, by definition, fundamentally nearly-decomposable or even indecomposable.
(4) It allows simultaneous consideration of multiple enterprise state-space contingency configurations shaping expected enterprise change regimes, design targets, change strategies, and modeling choices.
(5) It places central emphasis on computational enterprise architecture modeling and simulation not only to help design the enterprise transformation process but also as a new way of doing science. This would help generate new scientific knowledge to advance complex enterprise systems architecting and engineering.

Second, the proposed framework overcomes the shortcomings of the dominant planned change approach to enterprise transformation, as well as the weaknesses of such conventional methods as systems engineering, in dealing effectively with enterprise complexity and dynamics. An important contribution of the paper is to map out the multiple enterprise contingency conditions by explicitly considering both the time-scale for change and the enterprise's interactions with its evolving environment in order to frame what types of enterprise regimes to anticipate, what enterprise architecture design targets to aim for, and what change strategies to pursue for successful enterprise transformation. In this context, the proposed framework maps out when to use a modified planned change strategy and when to use emergent change strategy.

Modified planned change (e.g., mosaic change) is well-suited for relatively stable environments, are performed over regular time periods (e.g., by resetting near-term transformation roadmap every year and resetting the longer-term roadmap every three-to-five years). Meanwhile, the emergent (or guided) change strategy is well-suited for relatively unstable environments. The emergent strategy is performed on an on-going basis (in tune with the "organizational becoming" thinking gaining momentum in the organization science literature). In pursuing such a strategy, the near-term and longer-term implementation plans would be linked over time on a rolling basis. Emphasis would be placed on pursuing change initiatives with "generative properties" expected to open up new future improvement opportunities enhancing flexibility, agility and responsiveness. Change initiatives with "generative properties" would further be expected to enable greater reconfigurability of organizational capabilities, as well as to induce greater learning and adaptation.

Third, the paper defines the larger future intellectual agenda for a new discipline on *complex enterprise systems science, architecting and engineering.* This new discipline is defined to encompass integrative enterprise science concepts and principles from multiple knowledge domains, which currently remain largely inaccessible and highly fragmented. It is also focused on enterprise architecting and engineering, as a new field of practice. Finally, the new field is envisioned to place central emphasis on computational enterprise modeling and simulation, not only as part of the practice of enterprise architecting and engineering but also, equally importantly, as a new way of doing science, to create a science-based knowledge base that can be deployed to address challenges of complex enterprise change and transformation.