A System Dynamics Exploration of Agency Theory Interpretations of ERP Acquisition Methods in DOD

Allen Moulton
MIT Sloan School of Management
and MIT Engineering Systems Division
amoulton @mit.edu

Farrah Tazyeen
MIT Engineering Systems Division
ftazyeen@sloan.mit.edu

David K. Becker
The MITRE Corporation
dbecker@mitre.org

Stuart E. Madnick
MIT Sloan School of Management
and MIT Engineering Systems Division
smadnick @mit.edu

ABSTRACT

Implementing ERP is difficult. We examined three Department of Defense ERP programs: one a success, one delivering value many years late, and one a total failure. Misaligned incentives between stakeholders especially sponsor organization and system integrator, failure to accommodate rework in the master project plan, choosing the right contract terms, lack of in-house technical expertise, control of sponsor over project execution were some of the aspects which emerged to be important during the case study analysis. We used System Dynamics to model Agency Theory concepts to help in evaluating the alternative project governance structures of Lead System Integrator v/s In-House project management. We consider factors such as the sponsor's ability to adjust the customization component estimations, effects of incentives to expand scope through change orders, and the credibility of the contractor-staff working on the project. This paper sets an outline for importance of governance models and delving deeper onto the process of selecting a contract model and setting incentives which help align the goals of the contractor to those of the sponsor organization. [1]

1. Introduction

In the past 15 years, the U.S. Department of Defense (DOD) has embarked on at least fourteen large-scale, long term programs to replace many hundreds of legacy business software systems with vendor-supplied enterprise software (ERP) systems. As of 2011, the cumulative cost exceeded $9 billion with an additional $1 billion being spent per year. Out of those efforts, only a few have reached the point where they are delivering business value and some have been cancelled without ever producing any value despite spending over a billion dollars. On the other hand, there are other instances of successful business transformation achieved in DOD at much lower cost using similar ERP system technology.

[1] The authors would like to thank Mr. Richard Herrick, Mr. Kelly Hughes, Ms. Sarah Kingensmith, and Mr. Ian Macurdy at the Defense Intelligence Agency and Mr. Douglas Marquis at MIT Lincoln Laboratory, for their valuable insights into the issues addressed in this paper. The work reported herein was supported, in part, by the MIT Lincoln Laboratory and the Defense Intelligence Agency (DIA) under the "Understanding the Challenges to Net-Centric Systems and Mitigating Approaches" project, MIT Lincoln Laboratory contract 16-11-TCO-0013. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and not are not intended to imply concurrence with or the official policy or position of MIT Lincoln Laboratory, the Defense Intelligence Agency, the Department of Defense, or the MITRE Corporation.

In this work we applied System Dynamics to explore how Agency Theory can help explain some of the differences in outcomes of ERP adoption in the context of DOD. We briefly outline the results of investigation into three cases: one a success (Army Picatinny eNova), one that is slowly achieving some of its goals (Air Force DEAMS), and one that failed completely and expensively (Air Force ECSS). From the cases we found that contracting and governance were key causal factors. While the model presented here captures some elements of a complex process, we anticipate expanding the current model to incorporate other factors that will improve its explanatory power.

1.1 Challenges Facing ERP Implementations

ERP stands for Enterprise Resource Planning. The definition of ERP is 'packaged business software system that enables a company to manage the efficient and effective use of resources by providing a total, integrated solution for the organization information-processing needs' (Nah, Lau, & Kuang, 2001). The functionality performed by ERP systems is not new. Most organizations have established "legacy systems" that were developed as independent applications to support various business processes. A common issue with legacy systems is that operate as independent silos which hinder data exchange or automating processes across applications. The interfaces across legacy systems add an additional layer of complexity. Legacy systems are also often built on different older technologies that become difficult to support and may lack sufficient documentation to enable maintenance.

There are many reasons why an organization implements an ERP, some of which cited from literature (Ross and Vitale, 2000) are: need for a common IT platform, process improvement, data visibility, operating cost reductions, increased responsiveness to customers and improvements in strategic decision making.

Instead of many separate software applications, an ERP system brings business functionality together into a single standard package developed and supported by an outside vendor, such as SAP or Oracle. Differences in data are resolved by storing data in a common database which all application functions work against. A common database enables elimination of redundancy and enforcement of rules to create a common location and authoritative version of each piece of data. ERP systems also enable an enterprise to benefit from the substantial R&D budget of the Commercial Off-the-shelf (COTS) vendor and the experience that the vendor has gained from working similar applications in many other enterprises.

Business software is not an end in itself. The payoff comes from the improved business processes supported by the software. In fact, software enforces a business process design and rules of operation. One of the critical steps in implementing an ERP is to match the organization's current and desired business processes and rules to what the ERP supports. This step is often called "blue-printing."

ERP packages come with configuration options that allow them to adapt to different client needs. Nevertheless, since ERP systems require a standard way of doing each task across the enterprise, most organization find that they must 1) change existing business processes that people are accustomed to and/or 2) invest in customization of the ERP system. Customization is such a common phenomenon that there is an acronym for it, RICE (Oracle 2008):

- Reports refer to the custom reports required, that are not available as standard reports in the core ERP module.

- Interfaces refer to the interfacing with the external/legacy systems.
- Conversions refer to the programs required to transfer data from legacy to the ERP module.
- Enhancements refer to the additional functionality required by the existing system with no disturbance to the core functionality.

Customization with RICE can look like an advantageous choice, since the ERP project does not have to impose change on the rest of the organization. But RICE come at a price. They cost money to design, develop, test, and deploy. They add complexity to the system. And they need to be maintained and changed as the ERP package and the organizational environment changes. As Ketrick et al. (2011) put it: "An organization that decides to implement more than a few dozen RICE objects may be surprised by the difficulties that ensue."

An organization implementing an ERP needs to have clear goals in mind. Is the goal to replace legacy systems, to achieve significant capability over existing systems or to change internal business processes to meet new standards, or all of the above? When the goal is merely to replace legacy systems in order to have the maintenance and support external to the organization, factors such as data conversions, redesigning the organizational processes based on available technology, also termed as Business Process Re-engineering (BPR) (Snabe, Rosenberg, & Møller, 2008) play a crucial role. When the goal is to achieve significant capability over the existing legacy, then the sponsor organization will have to develop metrics to evaluate the functional goals desired. If the COTS ERP package fails to deliver on the metrics identified by the sponsor, then the entire process of ERP implementation consuming time, resources and money would fall short on its expectations.

Different organizations have different ways to measure success. A common definition would be to complete the ERP implementation within schedule and budget. Many ERP implementations experience over-runs in schedule and budget. Panorama Consulting Group (2011) found that 74% of ERP projects exceeded budget constraints and 61% of projects took longer than expected. The definition of "complete" also varies. One study (Deloitte Consulting, 1998) found that "Go Live" was the definition used by 34% of the respondents; 49% of the respondents felt that the process is never complete and that transformation is an on-going activity; while 3% of the respondents believed that completeness is achieved when the legacy is turned off.

1.2 Major Phases of ERP Adoption Process

The organization implementing the ERP is referred as the Sponsor Organization. Often due to lack of in-house capacity or expertise, a third party organization, referred as the Contractor, is hired for executing the process of COTS installation, implementation and meeting the sponsor's goals. Figure 1 represents the relationship between ERP Vendor, Implementation Contractor and Sponsor Organization. The contractor offers implementation services in exchange for contract price, after the selection of ERP package is done by the sponsor organization. In some situations, the vendor could also act as the contractor offering customization and implementation services.

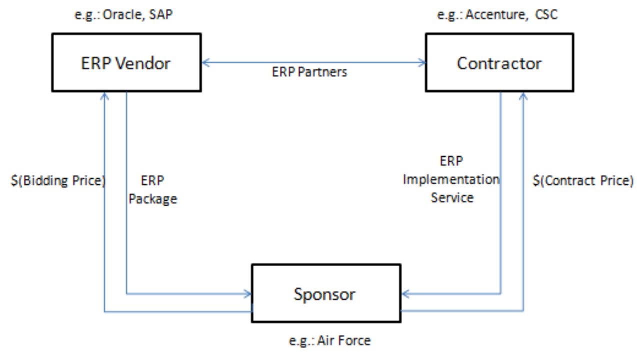

Figure 1: Vendor-Sponsor-Contractor Relationship

The major phases of ERP Life cycle are acquisition, implementation and maintenance. Acquisition refers to the phase of careful package selection and "presents the opportunity for both researchers and practitioners to examine all the dimensions and implications (benefits, risks, challenges, costs, etc) of buying and implementing ERP software, prior to the commitment of formidable amounts of money, time and resources" (Verville, Palanisamy, Bernadas, & Halingten, 2007). Verville et al have described the acquisition stage as a six stage process of planning, information search, pre-selection, evaluation, choice and negotiation. The planning process entails identifying the resources responsible for making the ERP purchase decision, defining requirements, establishing selection and evaluation criteria for COTS selection, marketplace analysis, choosing the acquisition strategy and anticipating acquisition related issues. All the activities help in identifying the organizational goals and choosing the right package after careful analysis of all available products in the market.

The implementation phase starts once the ERP source selection is complete. The process of identifying the mismatch between COTS product selected and the organizational goals, recruiting an implementation team in-house or selecting a contractor for the transition of legacy onto the new system fall under the implementation phase. Other activities included in this phase are: ERP set-ups, development effort for customizations required, data transfer from legacy to ERP, training of end-users and deployment.

The maintenance phase refers to addressing problems post deployment. Any updates in the ERP package or issues encountered by the end users are corrected with the help of implementation contractor or ERP vendor; based on the contract terms identified during the acquisition and implementation phases.

2. Experience with ERP Adoption in DOD

Although the conventional definition of acquisition phase ends at the selection of ERP package, in DoD projects have a much broader definition of "ERP acquisition" to include all the system development from blueprinting through RICE to software integration and test, but not the business process change management, training, data preparation, or rollout. The DOD "approach separates these dependent activities under discrete leadership and without the day-to-day participation of a single accountable leader who can quickly make decisions across all these elements of a program. The result is much slower decision making than encountered in industry programs. This a contributing factor to the excessive size, high cost, and lack of success in the fielding of the ERP programs." (Ketrick et al. 2011, p.19).

2.1 Army Picatinny Arsenal eNova

In the mid-1990s the Army Armament Research, Development, and Engineering Center (ARDEC) at Picatinny Arsenal was faced with closure unless it revamped its business processes to be more competitive with alternative suppliers of similar services. This required restructuring its financial processes to be project deliverable based rather than cost-plus service based. The IT unit at Picatinny decided to adopt SAP's ERP package to implement the new business processes. SAP was chosen because it had been proven at Raytheon and other business with similar needs.

Picatinny has strong IT skill sets needed for the products it develops. The project was controlled by in-house staff that built up its knowledge of SAP as the effort proceeded. SAP consultants provided specialized knowledge. Local IT contract workers provided extra capacity to perform tasks managed by Picatinny IT. Given the threat of base closure, everyone on the base was on board with changing business processes, from the base commander on down.

Beginning in 1999, the eNova project was developed in phases of less than two years each, allowing successive base commanders to see finished results before rotating to another position. To meet these goals, software customization and RICE were tightly controlled and largely avoided. The business processes at the base were changed to match the way SAP works rather than trying to change SAP to match legacy processes.

Today eNova supports 5400 users in five locations supporting financial accounting, cost controlling, asset management, project planning and execution, sales and billing, materials management, product lifecycle management, production planning, and human resources. All functionality uses configured SAP modules with minimal RICE.

Picatinny won a Baldridge Award for process improvement and has become an Army ERP Center of Excellance.

2.2 Air Force DEAMS

While eNova was successfully implementing its first phases of ERP, the Air Force initiated efforts in 2003 on the Defense Enterprise Accounting and Management System (DEAMS) intended to modernize accounting in the Air Force. While eNova was early enough, small enough, and focused enough to fly under the radar and assemble its ERP a piece at a time, the Air Force is huge and was required to follow changing heavy-weight rules of defense acquisition in adopting ERP. Both the ERP (Oracle) and a Lead System Integrator were put on "Firm Fixed Price contracts via the Enterprise Software Initiative (ESI) blanket purchase agreement (BPA) [as was then] was mandated for ERP implementations." (Ketrick et al. 2011, p. F-1)

As Ketrick et al. (2011, p. F-2) note, "Under FFP, the Government loses visibility into the data that underlies the performance of the contract. Since the vendor, in theory, takes on the risk of delivering successfully, they typically are not required to give the Government transparent visibility into the resources they apply or their activities as they execute their tasks. Consequentially, the Government is unable to identify problems prior to formal presentation and acceptance of deliverables."

DEAMS struggled. After years of trouble with FFP, DEAMS restructured its contract model to give the government more control. Twelve years after it started, DEAMS is part way through its roll out to Air Force installations.

2.3 Air Force ECSS

The Air Force Expeditionary Combat Support System (ECSS) was an ambitious effort to transform all Air Force logistics via ERP. ECSS began in 2004 and was cancelled in 2012 after spending over a billion dollars without delivering any business value. ECSS was even more complex than DEAMS, reportedly the largest ERP ever attempted with 1000 staff members working on it at a time.

Like DEAMS, ECSS acquired Oracle and hired a Lead System Integrator through a FFP bidding process. Like DEAMS, the government could not control the project sufficiently, since there were too many unknowns to make FFP viable. ECSS attempted to restructure the project and its management several times, but after being unable to deliver any viable systems, it was finally cancelled in 2012 and the Air Force returned to its legacy systems.

3. Critical Success Factors (CSFs) for ERP Implementation

In a large organization with hundreds of divisions and multi-site operations, it becomes really important to choose the right implementation strategy. The two most widely discussed implementation strategies are: Big Bang and Phased approach (Neal, 2010).

- <u>Big Bang</u>: *Implementation happens in a single instance*. The entire processes are moved at once from the legacy to the new system. The implementation is quick and very risky. Proper planning has to be done prior to implementation, as the legacy system is shut down as soon as the new system starts to operate.
- <u>Phased</u>: A phased implementation is done in phases, over a period of time. The phases are rolled out either on the basis of modules, business units or geography. This type of implementation works out when it is a large organization and the users can adapt themselves as they go along. The experience and learning from the initial phases could help in better planning of the later phases. However, this is a costly and lengthy approach compared to the Big Bang, as the legacy systems need to run in parallel until the transition is complete.

When integrating one module at a time, there comes a need to develop integration elements which can temporarily connect to the existing legacy system so that the business processes are consistent and running until the next phases of the remaining modules are implemented. This is important but ultimately results in an effort which eventually has to be trashed when the ERP implementation is complete. The system integrators or contractors play an important role here. The potentially conflicting relationship between project sponsors and contractors has been analyzed in detail by McKenna (2005). Contractor profit motivation discourages re-use of components and encourages raising variation orders for temporary integration elements. With unclear scope and lack of understanding of the requirements, the chances of variation orders being generated grows. This could lead to a number of after-effects directly impacting the schedule and budget of the project. McKenna has also emphasized its effect on the working relationship between the two parties leading to reduced communication in the integration activities; thereby contributing to the reinforcing loop of increased variation orders.

Critical Success Factors in ERP Implementation

In other research studies done by Willcocks and Syke, it was stated that "In practice, the need to identify and build key in-house IT capabilities before entering into ERP projects emerges as one of the critical—and neglected—success factors" (Willcocks & Sykes, 2000).

Somers and Nelson (Somers & Nelson, 2004) segregated the 22 CSFs into "players" and "activities" and ranked their importance across the different stages of the ERP lifecycle based on their research through data collection from Fortune 500 firms and random sample of 200 organizations using ERP systems. Players that have a key role in the initiation, adoption and adaptation stages are: top management, project champion, steering committee, implementation consultants, the project team and vendor-customer partnership. The activities that are crucial are: careful package selection, management of expectations, project management, customization, data analysis and conversion, business process reengineering, architecture choices, dedicating resources, clear goals and objectives, interdepartmental communication and interdepartmental cooperation.

Careful Package Selection

There are many ERP packages in the market, and they differ from each other in one way or another. Some ERP packages might suit large organizations while some other may be more appropriate for small organizations. Similarly, the compatibility of a package to an industry might differ. "Choosing the right ERP packaged software that best matches the organizational information needs and processes is critical to ensure minimal modification and successful implementation and use. Selecting the wrong software may mean a commitment to architecture and applications that do not fit the organization's strategic goal or business processes" (Somers & Nelson, 2001).

When choosing the right package, a careful analysis and comparison of the ERP application with the organization's business process will help in estimating the extent of customization required. Choosing a wrong package would either mean extensive customizations or changing the business processes in the organization to match up to the ERP functional capabilities. The decision between customizations and BPR is an organizational wide decision involving multiple stakeholders, and has to be evaluated based on its impact on organizational competencies, end users and budget available for customizations.

Some of the questions that arise from the implementation perspective are: Is it possible to identify all the customizations required in the 'Initiation' phase of the project? Were they included in the goals and objectives? How to tackle new customization requests after the 'Initiation' phase?

Top Management Commitment

"Implementing an ERP system is not a matter of changing software systems, rather it is a matter of repositioning the company and transforming the business practices" (Bingi, Sharma, & Godla, 1999). Any organization has its own competitive advantage in the market through its business processes. Implementing an ERP could change their positioning; and hence, an ERP implementation has to be treated as a strategic choice rather than a mere IT implementation. Top management must be involved throughout the project implementation in managing this change and resolving any conflicts. Re-emphasis from the top management on the motivations and reasons for this transformation will keep the employees informed and contributing; rather than opposing the change. As per the survey done by Fiona et al (Nah, Zuckweiler, & Lau, 2003) on the Chief Information Officers' Perceptions of Critical Success Factors, top management support was cited as "the only way to get started" and to get "compliance and commitment from divisions". Involvement of top management helps improve inter-departmental cooperation and allocating the necessary and dedicated resources of the organization.

4. Agency Theory – Relevance to the Relationship between Contractor and Sponsor

When an organization plans to implement an ERP, it might not have the necessary in-house IT expertise to successfully replace the legacy system. The external contractors are hired by an organization after a careful selection of the ERP package has been done. Although the ideal expectation of the organization is to have the contractors do the best job in the shortest amount of time, with the least resources, and within budget; it would be impractical to ignore their self interests. When hiring external contractors, the factors that need to be considered from a project management perspective increase.

In 2003, Haines and Goodhue (Haines & Goodhue, 2003) used the Agency Theory (Eisenhardt, 1989) to establish how contractor involvement and their motivations affect the outcome and direction of any ERP implementation. The following is the summary of their research; following which an attempt to model these findings using system dynamics has been made.

The two key issues that are significantly important with respect to implementation contractors are: "the extent of the involvement that contractors have and second, the level of knowledge held by the organization implementing the ERP system (the sponsor) as well as the transfer of knowledge between the vendor, contractor, and the sponsor."

The contractors generally offer the following services: configuring the new ERP to fit the organization; transferring the legacy data and processes onto the new ERP; customizing the ERP package to fit to the business needs of the organization; and directing the organization to adapt to the new business processes as offered by the ERP.

Application of Agency Theory in the Context of the Sponsor Organization and the External Contractors

Agency theory talks about the structure of relationship between two parties, principal and agent, who are engaged in a common goal; but have different incentive structures and attitudes towards risk. In the context of the current problem at hand, the principal is the sponsor organization and the agent is the external contractor.

The three characteristics of this relationship are: goal differences, risk tolerance differences, and information asymmetry (Eisenhardt, 1989). The primary goal of an external contractor is to earn revenues and profits. Contractor firms also have an incentive to create relationships with their clients and maintain/build reputation. In some types of contract situations, short term incentives of the project team can prevail over long term reputation of the firm.

Information Asymmetry: The information that each party has may or may not be transparent in the relationship. Especially in terms of a fixed price contract, the sponsor might hold back some information like business processes of the organization or subtle business requirements which might eventually demand more work from the contractor's side. Similarly, the contractor might portray a different picture about their expertise and the internal workforce; and "ways in which they can cut corners in carrying out the project" and increase the contract duration beyond schedule to earn more revenues. After the contact has been signed, some of this information might surface which could eventually have negative impact on the working relationship.

The two types of agent opportunistic behavior are: **adverse selection** and **moral hazard.**

- **Adverse Selection: "**Misrepresentation of ability by the agent".
- **Moral Hazard:** "Agent might not act as diligently as expected in carrying out the will of the principal."

Agency theory proposes two basic control strategies to monitor the agent's behavior and evaluate their performance - outcome-based and behavior-based. Outcome-based relies on evaluating the performance of the contractor based on the outcome of the project. This is a risky approach as these projects involve huge investments of time and money and lack of early evaluation could be destructive both for the relationship and the project. The behavior-based approach is much more practical in this situation. However, as Kirsch (1996) pointed out, the principal's ability to effectively evaluate the agent's behavior is severely limited by the principal's knowledge about the task.

Impact of the Sponsor's Knowledge

When the sponsor has sufficient knowledge of its legacy business processes and the technical knowledge on the integration elements and the customization efforts required, then it is easier for the sponsor to gauge the behavior of the contractor. For example, when a "Change Order" is raised by the contractor, sponsors are in a better position to judge whether it is valid or is it just another opportunistic behavior by the contractor.

Haines and Goodhue propose that when hiring a contractor, it is essential to define (a) the level of involvement and (b) the role the contractor assumes. The level of involvement is the number of contractor-staff working on the project and the depth of their responsibilities. The role of the contractor is whether they are assigned the responsibility of project management and strategic planning along with technical implementation.

The control of the sponsor over the project timelines and budget is severely affected when the contractor is responsible for the project management. That gives the contractor more opportunity to run the project as per its terms, incentives and risk assessments. When the sponsor has no technical knowledge and lacks experience dealing with IT implementations, then the contactor has all the opportunities to drive the budget as per its interests. Hence, there needs to be the right balance of power between sponsor and contractor for successful project implementation.

Knowledge Transfer from the Contractor to the Sponsor Organization

Adverse Selection: According to the interviews conducted by Haines and Goodhue, organizations were unsatisfied with the expertise of the contractors; and felt there was more on-the-job learning i.e. the project team did not have sufficient implementation knowledge and built upon their expertise while working on the project, therefore performing at a pace below expected and causing a delay in project completion.

Moral Hazard: With the differing goals and incentives of the contractor from the sponsor, contractors might want to perform work at a pace that is more in favor of their interests; or create additional work to generate additional revenue. Thus, it is important to understand how to monitor the progress of contractor's work and have the project management responsibilities assigned to people within the sponsor organization.

How can we solve the above two problems in the following two different situations?

(1) The sponsor organization has limited or no IT knowledge

(2) The sponsor organization has an IT department which has sufficient capability to develop ERP related skills and benefit from the contractor's knowledge transfer, thus being able to develop/maintain future phases of the implementation.

4.1 Different Models of Governance for Large Projects

Figure 2 below outlines different ways of governing large system projects and the impact of each governance type on the external environment (Sapolsky, 2009).

	Arsenal	Contract	Weapon System Manager	Outsourcing To Private Arsenal	Lead System Integrator
Program Requirements	Government	Government	Government	Government	Industry
Technical Direction	Government	Government	Government	Industry	Industry
Program Management	Government	Government	Industry	Industry	Industry
Technical Execution	Government	Industry	Industry	Industry	Industry
External Environment	▪ Infrequent wars ▪ Little commercial application of military tech	▪ Some commercial application of military tech ▪ Private sector private sector pays better, can be more responsive	▪ Weapons become more complicated / complex ▪ Coordination of sub-systems becomes important ▪ Large companies can better leverage political support	▪ Government begins to lose in-house tech capabilities ▪ Outsourcing becomes increasingly acceptable	▪ Loss of in-house government tech capabilities leads to inability to define what's possible

Figure 2: Program Responsibility Format Types (Sapolsky, 2009, pp. 26)

In the Lead System Integrator (LSI) model, all the responsibilities are completely outsourced, potentially resulting in a loss of in-house competence and loss of control on project execution. The Arsenal model is at the other end of the spectrum, where all responsibilities are fulfilled in-house. This would require the government to employ people with the relevant skill sets and keep them employed even when the implementation phase is completed. This could also be done by contracting these people from external service organizations for the duration of the project. The government DoD projects started with the LSI model, and are now moving towards Contract model; where the program requirements and program management are all in-house and an external systems engineering advisor, who is well experienced with ERP package, is hired for technical direction. The technical execution is the only role outsourced to the contractor in this model. The government is leveraging the experiences gained from Air Force ERP implementations and collaborating with the external advisor to develop a center of excellence in-house; which could help future program implementations adopt the Contract model of governance.

5. System Dynamics Modeling

5.1 Contractor Governance

Based on the Agency Theory, the following causal loop diagram demonstrates the way the contractor adopts for opportunistic behavior. If the Sponsor organization has no internal IT competence to evaluate the technical developments in the project, the gap in implementation knowledge increases resulting in lesser transparency of the contractor's technical competence and achievements within the project. This gives the contractor an opportunity for moral hazard thereby creating further information asymmetry between the contractor and the sponsor, reinforcing the knowledge gap, as depicted in Figure 3 below.

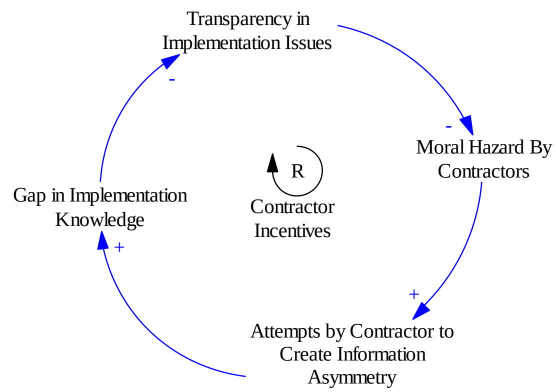

Figure 3: Contractor Incentives

McKenna (McKenna, 2005), in his paper "Projects with Contractors", has explained the Variation Order – communication loop. The following causal loop diagram in Figure 4 illustrates the same. With more contract variation orders raised by the contractor, the budget is bound to get affected thereby reducing the sponsor satisfaction with the contractor's performance. This could affect their working relationship and might curb down on the integration activities. Thus, the gaps between what capabilities are desired and what solution is being offered grows, leading to further generation of variation orders. Figure 4 below demonstrates the causal effects of variation order- communication loop (McKenna, 2005).

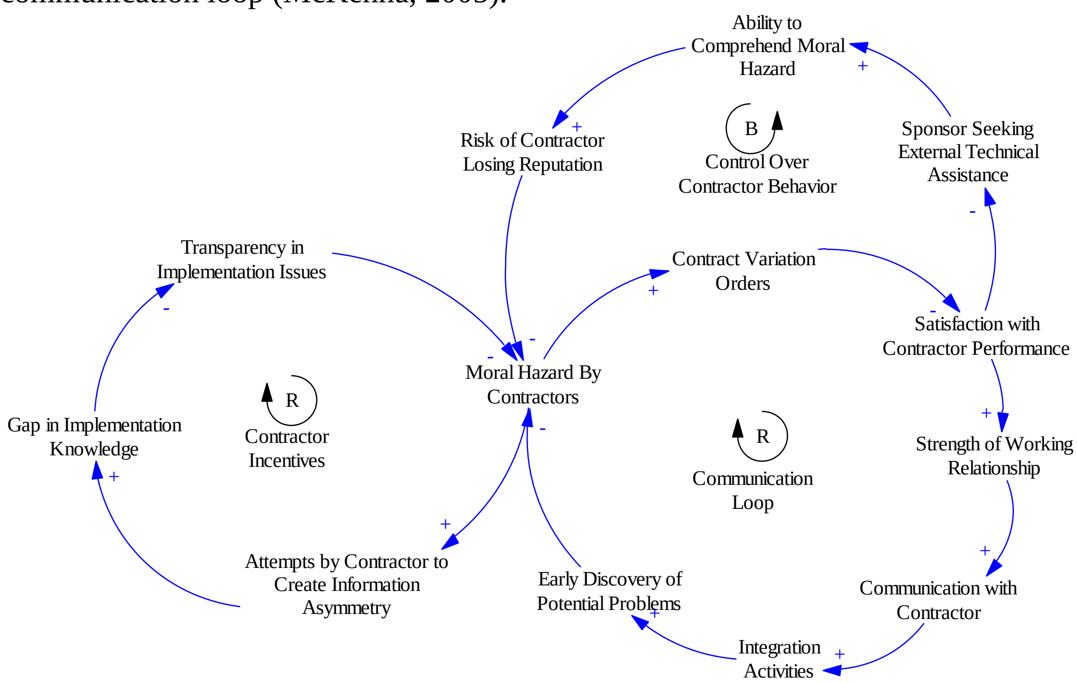

Figure 4: Incentives to Hire Technical Advisor

Both DEAMS and ECSS projects brought in a systems engineering advisor for the technical oversight. If the sponsor organization has no internal expertise to evaluate the progress and quality of the project, it becomes extremely difficult to have control on the contractor's behavior. Having an advisor would help in reducing the implementation knowledge gap and thus the sponsor would be able to better comprehend the contractor's activities. This in a way also keeps a check on the contractor in not opting for moral hazard, as their activities are more transparent and the risks of losing reputation increases. In the following causal loop, the balancing loop 'Control over Contractor Behavior' explains the above phenomenon.

The above causal loop shown in Figure 4 supports the idea of having technical oversight on the contractor to avoid information asymmetry and moral hazard issues. This causal loop diagram illustrates the ability of the sponsor organization in being able to better predict the estimations of the RICE components in the project management in-house scenario in the system dynamics model.

5.2 Description of the Model

The system dynamics model attempts to address the impact of a few project management levers on the overall project schedule. The elements below are discussed in the following sections:

1. Classic Rework Model
2. Contractor's Comprehension on Requirements
3. Addition of New Work
4. Adverse Selection by Contractor
5. Staffing
6. Effect of Experience on Productivity

5.2.1 Classic Rework Model

We employ a classic rework model (viz. Cooper and Mullen 1993). In conventional project planning, the master schedule constitutes all the tasks required to accomplish, with timelines against each of them. However, when the project is initiated, there could be uncertainties either in terms of technical understanding or functional requirements. Also, the initial requirements identified could have defects and the sponsor's perceptions could evolve over time. Under all these circumstances, there is a parallel generation of rework along with the work correctly done. The factor Fraction Correct and Complete (FCC) represents the extent to which the work being accomplished is correctly done. Thus, FCC represents the percentage of Work Being Accomplished moving into the stock of "Work Done". The remainder of the Work Being Accomplished i.e. *(1-FCC)*Work Being Accomplished* flows into the stock of "Undiscovered Rework". The discovery of this rework takes place after the project has been demonstrated to the end user, during unit testing, or as the development team gains further experience with project implementation. This discovered rework gets added onto the stock of "Work To Do".

Work Done Correctly = Work Being Accomplished*Fraction Correct and Complete

Rework Generation = Project Finished*Undiscovered Rework/Time to Discover Rework

The undiscovered rework can be of two types:

1. Undiscovered technical errors
2. Undiscovered functional change requests

LSI Model Behavior

In an LSI model, with the firm fixed price contract, the contractor is being paid the same amount of money irrespective of the technical rework generated. (The functional change requests might need re-negotiating the value of the contract depending on the impact). Thus, the incentives to stick to schedule are high in a firm fixed price contract and might drive the contractor in recruiting an experienced team, if the incentives for low peer review errors are set.

However, if the contract terms are on time and material labor hours, the lack of control of the sponsor in monitoring the errors generated due to technical incompetence, might drive the contractor in fixing the technical errors on paid hours. Thus, there is no incentive for the contractor to hire the best people on the job, as the rework is also raised as change requests and the labor is paid for all the extra hours.

Yet another behavior could be that the initial estimates provided by the contractor are on the basis of the level of experience in the team. Thus, the productivity of the team could be low, but could avoid creating technical rework as the staff has time to learn and implement.

Contract with Project Management In-house

In a contract where the project management is in-house, the discovery of rework can be closely monitored, and any technical errors can be excluded from the billing hours of the contractor. However, the effects on schedule due to these technical errors cannot be avoided if the contract is time and materials; and has no incentives to adhere to the schedule.

In an FFP, the contractor has to successfully accomplish a given number of RICE components within schedule. This ensures that the obvious technical gaps can be taken care of, within the fixed price budget. However, the not-so-obvious technical errors which determine the actual quality of the development effort would be compromised if sufficient time and effort is not dedicated to peer review process in the master schedule.

5.2.2 Contactor's Comprehension on Requirements

During the blue-printing stage, the contractor and the sponsor organization collaboratively work to address the gaps in the capabilities document, and refine the capabilities to generate system specifications. A prior knowledge of ERP will help in designing the requirements and demonstrating how the specifications can be met using the features in ERP. The functional design document (FDD) is generated, which has requirements to the lowest level of detail, and the design of any reports or user interfaces desired. There could be information asymmetry between what the sponsor desires and what the contractor has understood. If the functional design document can demonstrate in terms of prototyping or design look and feel, it could reduce this information asymmetry and the sponsor would be able to clarify the requirements during the design phase. Hence, the FDD quality measure depends on the following parameters, as shown in Figure 5.

1. Contractor's knowledge on ERP
2. Effectiveness of Integration activity

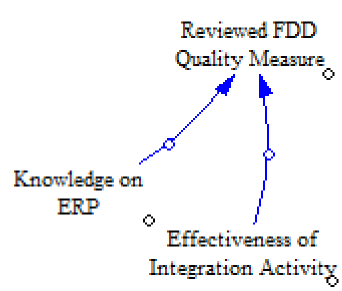

Figure 5: FDD Quality Measure

The law of garbage in garbage out says that if the requirements are not well understood, then the development will have to go through rework cycles. It could happen that the contractor misunderstands the requirements if it has no functional domain knowledge on the system being implemented. For example, it would be difficult for a contractor who has no Oracle manufacturing experience to be able to understand Oracle Costing methods.

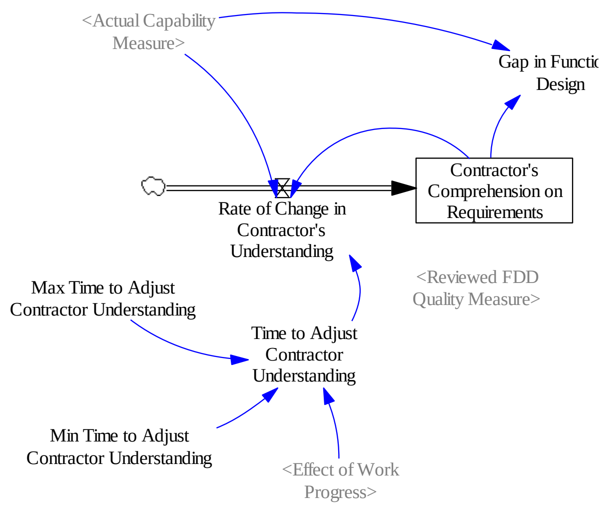

Figure 6: Information delay in Changing Contractor's Comprehension on Requirements

Figure 6 above demonstrates the phenomenon of change in contractor's comprehension of requirements. The stock "Contractor's Comprehension on Requirements" has an initial value of "Reviewed FDD Quality Measure". If the integration activity during blue printing was efficient and the functional design document was well understood and approved by the sponsor organization, then the value of "Reviewed FDD Quality Measure" is 1 and there is no gap in the understanding of the functional design.

If the value of "Reviewed FDD Quality Measure" is less than 1, then the Contractor's comprehension of the requirements gradually adjusts to 1 at the "Rate of Change in Contractor's Understanding". The time taken to adjust contractor's understanding is dependent on the work progress. Based on the work progress the time factor reduces from the maximum to the minimum.

Time to Adjust Contractor Understanding = Max Time to Adjust Contractor Understanding*Effect of Work Progress + (1-Effect of Work Progress)*Min Time to Adjust Contractor Understanding

Here, the maximum time to adjust contractor understanding can be treated as the time taken to receive feedback from the end user. Minimum time to adjust contractor understanding would be significantly less, say the time taken to complete two RICE components i.e. around 4 months. We do not have exact measure of what is the least amount of time taken; so we can assume it to be equal to two RICE components because once the next task in the critical path is completed, we get sufficient knowledge of what could be the issues with the previously completed task. As time progresses and as the contractor has achieved significant work progress, the time to adjust contractor's understanding of the requirements reduces drifting from the maximum time to minimum time.

The following is the graph of "Contractor's Comprehension on Requirements" with the following values for the contributing variables:

Minimum Time to Adjust Contractor Understanding = 0.25 years
Maximum Time to Adjust Contractor Understanding = 2 years

There are two simulations marked below with varying values of Reviewed FDD Quality Measure.
For (1): Reviewed FDD Quality Measure = 1
For (2): Reviewed FDD Quality Measure = 0.8

As shown in Figure 7, with Reviewed FDD Quality Measure = 1, the graph stays at 1. But with Reviewed FDD Quality Measure initially equal to 0.8, the graph for "Contractor's Comprehension on Understanding" follows a first order information delay.

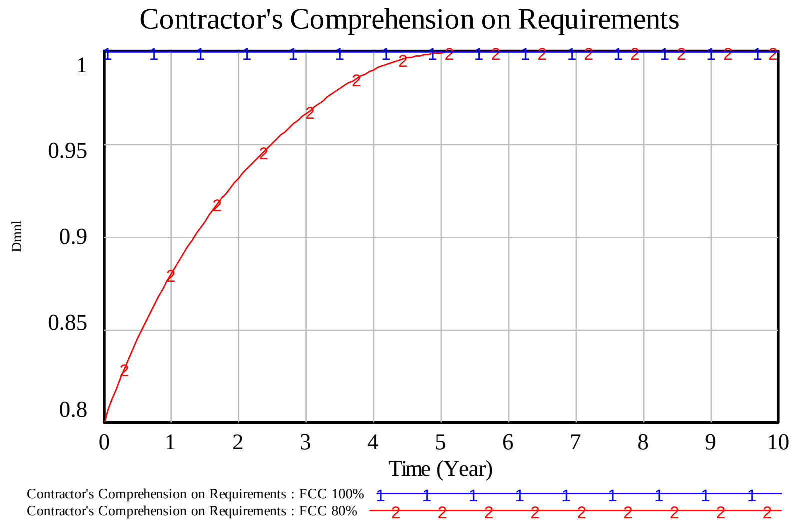

Figure 7: Simulations of Contractor's Comprehension on Requirements

Thus, if the initial blue printing is not efficient, the contractor's comprehension on requirements only improves as they gain experience with the accomplishment of work.

5.2.3 Addition of New Work

The ERP COTS package has frequent new patch releases to either resolve existing issues, or release new features. These packages could affect the database tables, look and feel of the UIs and also include additional functionality. However, the application of these patches requires additional work by the contractor, not only in the system upgrade but also additional activities such as re-validating whether the RICE components implemented works as expected after the patch application.

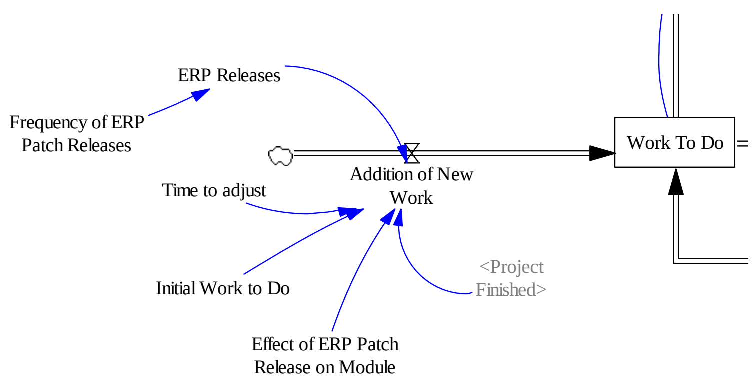

Figure 8: Addition of New Work Due to Patch Updates

Figure 8 above represents the process of new work addition with the release of new patches. The "Frequency of ERP Patch Releases" initially been set to 2 years, meaning new patches get released every 2 years; which adds significant work to the stock "Work To Do".

The variable "ERP Releases" has been set as a pulse input which gets triggered based on the Frequency of ERP patch releases, for example new patches are released at years 2, 4, 6, 8, 10 etc.

The variable "Effect of ERP Patch Release on Module" represents how much of the work gets affected, which needs re-testing, and what percentage of the actual work is the effort required for the re-application of RICE components. Depending on the severity of the patch release effect on functionality, the DoD might even have to undergo a re-blueprinting process; where the entire design is re-validated and adjusted as per the new changes. In a long term project, this factor has a significant impact on the design. The variable "Effect of ERP Patch Release on Module" is treated as constant for the sake of simplicity, with a value of 2.5% or 0.025 times the initial work. Thus, this adds an additional work of 25 tasks every 2 years.

5.2.4 Adverse Selection by Contractor

As discussed in section 4 on Agency Theory, describing the differing motivations of contractor v/s sponsor, here are some of the possible ways in which a contractor would leverage the lack of in-house knowledge in the sponsor organization:

1. Increase number of RICE components to increase revenues
2. Technical errors occurred during the project testing raised as variation orders
3. Adverse Selection, leading to higher estimations on tasks

If the incentive of the contractor, based on contract terms, is to increase the length of the project or to increase the work so as to gain more revenues, then the options mentioned above are commonly used for moral hazard. Even in a firm fixed price contract, it is usual to over emphasize the amount of work that would be required as part of RICE implementations, to get a better first deal on the fixed price.

The adverse selection has been incorporated in the system dynamics model. Figure 9 below is the associated causal loop from the model. The contractor might give a false impression on the expertise or the ability of people allotted for the project. There could be a significant number of new hires who have had very minimal experience working on ERP projects; and the contractor allots them to this project to learn on the job. To compensate for the time taken to get these new hires on the learning curve, the initial estimates of the project as proposed by the contractor could be overly pessimistic, meaning: a buffer is added to every task in the design document while giving estimations. This costs the sponsor organization not only additional time, but also additional costs, if the contract terms are cost-plus.

The ability of the sponsor organization to validate the initial estimates provided by the contractor largely depends on its experience with ERP project management and in-house technical expertise. In the two case studies, it was evident that DoD had minimal or no in-house technical expertise. However, DoD had eventually hired a Systems Engineering Advisor to have technical oversight on the contractor.

In an LSI contract model (as discussed in section 4.1), the entire responsibility of requirements definition, design, development, testing, deployment, support is with the LSI, and the sponsor has no control on the project execution. This gives the contractor an ability to propose initial estimates of work way above the actual work rate.

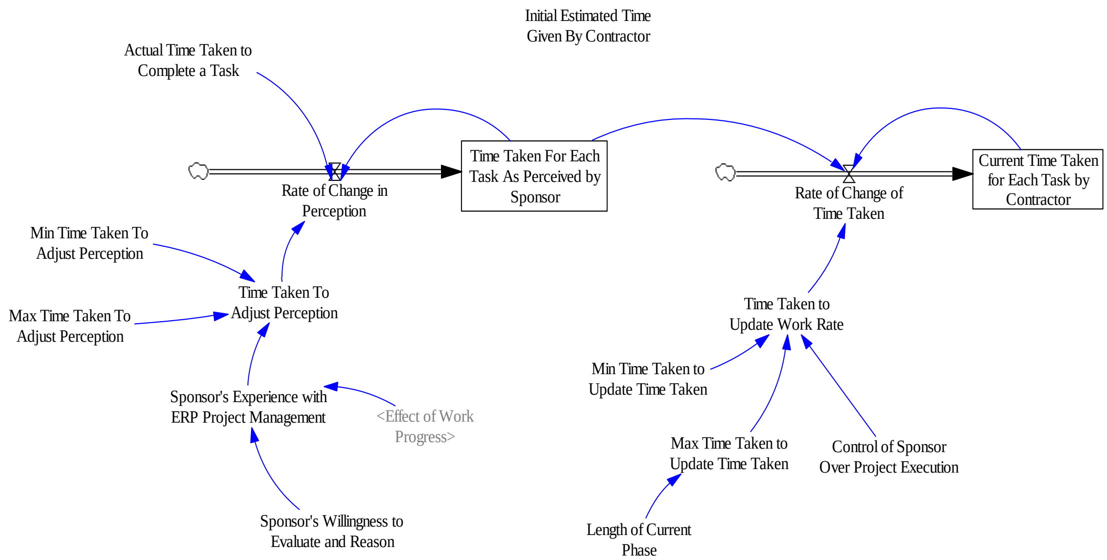

Figure 9: Representation to Adjust Adverse Selection by Contractor

Even in other contract models with project management in-house, the lack of in-house expertise paralyzes the sponsor from validating the complexity of the RICE components and their estimates. With growing experience in project management of ERP implementations and willingness to evaluate with other DoD program managers; the sponsor's perception of work rate gets adjusted to the actual work rate over time.

Although the sponsor's perception on the time required to complete a task has been updated to actual, the problem lies in re-negotiating the estimates with the contractor. The "Control of Sponsor over Project Execution" determines whether the estimates could be re-negotiated or will have to be changed only after the current phase. The power of the sponsor organization depends a great deal on the type of contract negotiated with the contractor, and the extent to which the sponsor is locked-in with the current contractor. The sponsor has the pressure of lock-in effects if the contract is substantially long and the sponsor is already half way into the project.

Thus, from the causal loop diagram in Figure 9, the initial value of "Time Taken for Each Task as Perceived by Sponsor" is the "Initial Estimated Time Given by Contractor". The flow "Rate of Change of Perception" is dependent on the "Sponsor's Experience with Project Management", which in turn is dependent on Work Progress.

The "Current Time Taken for Each Task by Contractor" represents the actual time being taken by the staff in performing a task. It's initial value is again the initial estimates proposed by the contractor. This value however gets influenced by the "Control of Sponsor over Project Execution".

The more control of sponsor over project execution, the sooner the "Current Time Taken for Each Task by Contractor" is updated to "Actual Time Taken to Complete a Task". Hence, the Productivity Desired by Sponsor which is initially influenced by the initial estimates given by contractor is updated more quickly to the efficient productivity levels.

In the Lead System Integrator (LSI) model, with a lack of control of sponsor, the "Current Time Taken for Each Task by Contractor" does not get updated quickly and hence, the Productivity Desired By Sponsor remains to be the same as the initial estimates proposed by Contractor.

In the Project Management In-house (PMI) model, with more control over project execution i.e. value of "Control of Sponsor Over Project Execution" equal to 1, the "Current Time Taken for Each Task by Contractor" soon gets updated to the "Actual Time Taken to Complete a Task", and hence "Productivity Desired By Sponsor" gets updated to the actual efficient productivity level.

5.2.5 Staffing

The staffing model uses a classic learning model structure (as in Abdel-Hamid and Madnick 1991) breaking total staff down into two stocks "New Staff" and "Experienced Staff". The relative experience of new staff could vary from 0 to any value less than 1, with 1 representing fully experienced staff. As the project progresses, the new staff gains experience and moves into the stock of "Experienced Staff" with a first order delay "Time to Gain Experience". As mentioned in the previous section, the initial estimates of any task proposed by the contractor might have a buffer factor to it, in order to accommodate the learning curve of their newly hired staff. In the simulations below, we assume that the staff size is fixed and introduced as initial New and Experienced staffing values at the beginning of the project.

5.2.6 Effect of Experience on Productivity

From sections 5.2.4 and 5.2.5, there are two types of productivity. Section 5.2.4 discusses the desired productivity as perceived by the sponsor organization, "Productivity Desired by Sponsor", which also represents the rate at which the staff is currently working. Section 5.2.5 describes the productivity based on the experience of the ERP staff in the contractor organization "Productivity as per Experience". There are two situations which could arise:

1. Productivity Desired by Sponsor > Productivity as per Experience
2. Productivity Desired by Sponsor < Productivity as per Experience

LSI Model Behavior

In an LSI model, the contractor has all the power with the sponsor organization having no major control on the project execution. In such a scenario, the time taken to complete a task as perceived by sponsor organization is driven majorly on what LSI proposes.
Thus, the contractor can suggest durations which have enough buffer time for the new hires to learn on the job.

Thus, the first situation of Productivity Desired by Sponsor being greater than Productivity as per experience is not really possible in the case of LSI model.

Contract with Project Management In-house

In a contract with project management in-house, the initial time taken for each task as perceived by the sponsor are the estimates proposed by the contractor. However, with close monitoring, and with the help of the Systems Engineering Advisor, the gap between perceived and actual time taken reduces, and the sponsor's ability to estimate RICE components improves.

In a situation where the sponsor has the actual time taken to complete a task, but the contractor does not have all the experienced people – the new hires are unable to adhere to the allotted time and hence, there are workarounds and the quality of the task performed is negatively affected.

This corresponds to the first situation where *Productivity Desired by Sponsor > Productivity as per Experience*. In other words, the staff is working at a faster pace than their capability. The impact on the quality of work is not seen directly; however, the undiscovered rework increases with a dilution in fraction correct and complete.

In the second situation where Productivity Desired by Sponsor < Productivity as per Experience, the staff works at a pace lower than their capability therefore causing no rework.

5.3 Analysis and Results

5.3.1 Ideal Scenario

The ideal scenario would be:

1. Reviewed FDD Quality Measure is 1
2. Effect of Experience on FCC = 0
3. "Initial Estimated Time Given by Contractor" is same as the "Actual Time Taken to Complete a Task" = 0.25 years
4. Initial Experienced Staff = 50; Initial Inexperienced Staff = 0

Figure 10 represents Work Done in the ideal scenario, with project finishing in 5.6 years.

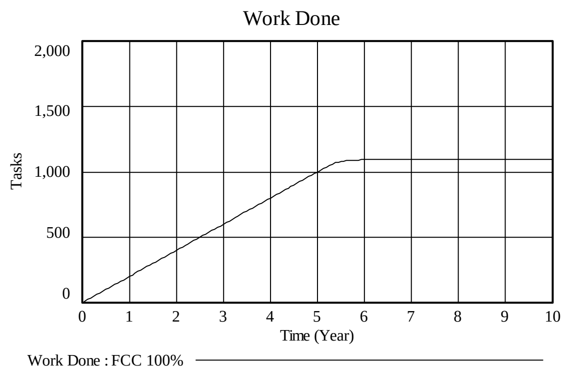

Figure 10: Ideal Scenario - Graph of Work Done

5.3.2 Experiments

Assumptions

The assumptions tested are: 1) When the productivity is as per the initial estimated time proposed by contractor, then the technical expertise work matches their pace and experience, and no technical rework is generated. 2) When the productivity desired by sponsor exceeds the productivity based on contractor experience, then there is schedule pressure and there are technical errors made during the implementation, therefore requiring rework.

The experiments below have been represented as either LSI model or Project Management In-house models (PMI) primarily on the basis of the value of variable "Control of Sponsor over Project Execution"; with a value of 0 and 1 for LSI and PMI models respectively. There might be other factors differentiating the LSI from PMI models, which have not been covered in these experiments.

LSI Model

With the LSI model, the contractor would be better off adding buffer time to the tasks. Hence, we could assume that the Initial Estimated Time Given by Contractor is much more than the Actual Time Taken to Complete a Task.

The following parameters are set for the LSI model:

1. Actual Time Taken to Complete a Task = 0.25 years
2. Initial Estimated Time Given By Contractor = 0.4 years
3. Initial Experienced Staff = 10
4. Initial Inexperienced Staff = 40
5. Knowledge on ERP = 0.9
6. Effectiveness of Integration Activity = 0.8
7. Maximum time to Adjust Contractor Understanding = 5 years
8. Control of Sponsor over Project Execution = 0

Project Management in-house (PMI) Model

The following parameters are set for the model:

1. Actual Time Taken to Complete a Task = 0.25 years
2. Initial Estimated Time Given By Contractor = 0.4 years
3. Initial Experienced Staff = 10
4. Relative Experience of New Staff = 0.2
5. Initial Inexperienced Staff = 40
6. Knowledge on ERP = 0.9
7. Effectiveness of Integration Activity = 0.8
8. Maximum time to Adjust Contractor Understanding = 5 years
9. Control of Sponsor over Project Execution = 1
10. Max Time to Adjust Perception = 1 year

Following is the comparison of the two simulations:

With the above two simulations, we could expect that the fraction correct and complete for the LSI model would be better than the PMI model because; in the LSI model, the sponsor has no control over the project execution and the LSI has the leisure to perform the activities at their initial pace and as per our assumption, this produces quality work. Thus, the technical rework in LSI is 0. Figure 11 below demonstrates the difference in FCC between the two contract models:

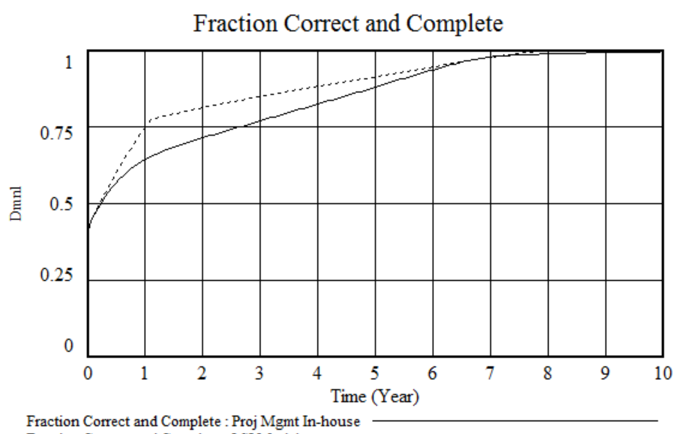

Figure 11: Comparison of Fraction Correct and Complete for LSI and PMI Models

Figures 12 and 13 present the comparison of Productivity as per Experience and Productivity desired by Sponsor for both the cases LSI and PMI models. In the PMI model, the Productivity desired by Sponsor is more than the Productivity as per experience (as shown in Figure 12), and hence the technical staff is working under pressure and thus, rework is bound to get generated.

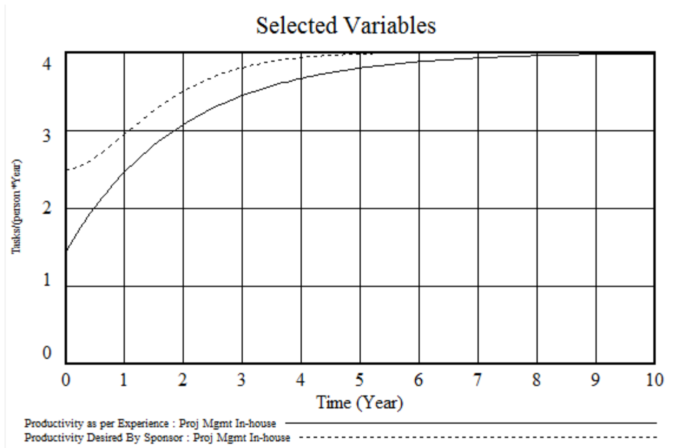

Figure 12: Comparison of Productivity as per experience and as desired by sponsor for PMI model

In the LSI model, the Productivity as per Experience outgrows the Productivity desired by Sponsor (as shown in Figure 13); and so the technical staff has the liberty to work at a slower pace than their capability. Thus, although technical rework is minimal in this case, there is a factor of “work expands to the time you have”.

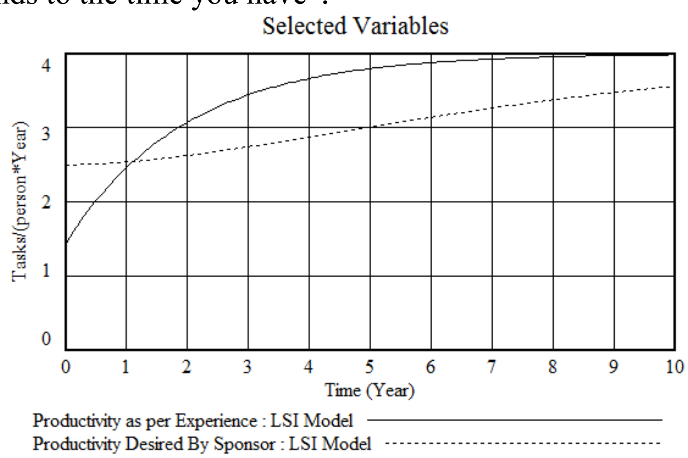

Figure 13: Comparison of Productivity as per experience and as desired by sponsor for LSI Model

Figures 14 and 15 represent the rework generation and work done correctly for the two cases:

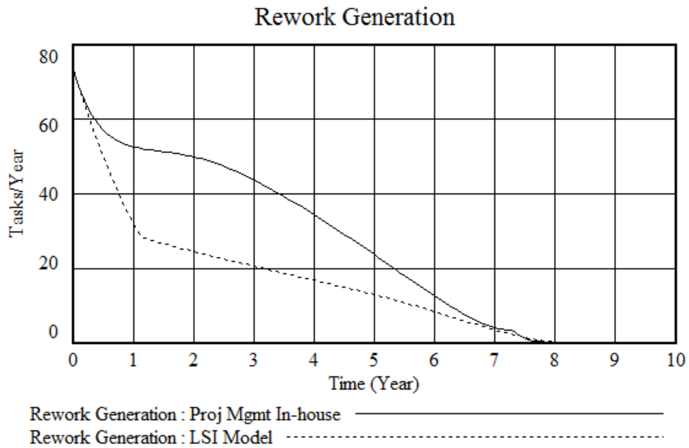

Figure 14: Comparison of Rework Generation for LSI and PMI Models

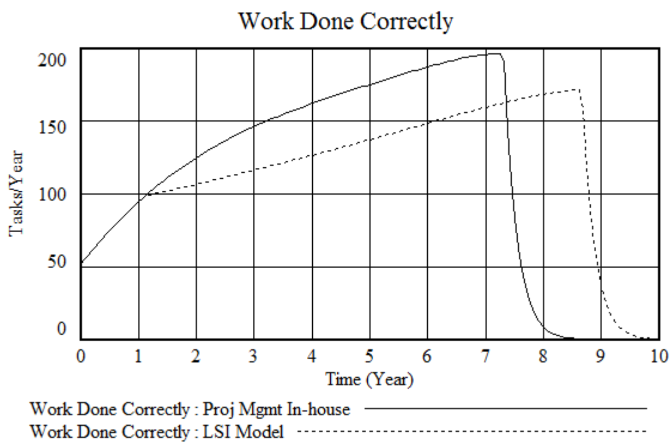

Figure 15: Comparison of Work Done Correctly for LSI and PMI Models

Although the rework generation in the LSI model is lesser than the PMI model (Figure 14), the work done correctly is significantly higher in the PMI case than in LSI (Figure 15). Hence, although there is some rework being generated, but due to the faster pace of work in PMI model, the technical contractors have a faster learning curve, thus the Effect of Work Progress is better off in the PMI model, as demonstrated in Figure 16 below. Also, the undiscovered rework in the LSI model will be discovered much later in the process due to the slower rate of improvement in "Effect of Work Progress" in the LSI model compared to PMI.

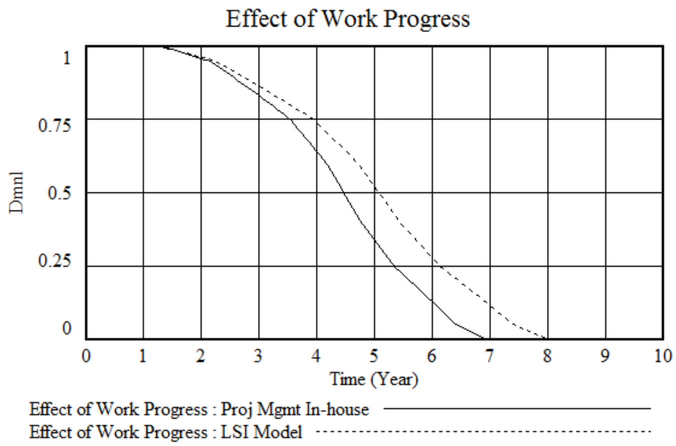

Figure 16: Comparison of Effect of Work Progress for LSI and PMI Models

Hence, the time to adjust contractor understanding reduces at a faster pace with the PMI model; with an accelerated improvement in the FCC over the LSI model.

Overall, Figure 17 demonstrates the comparison of the time taken to complete the project in the two cases, with PMI model being better off than the LSI model.

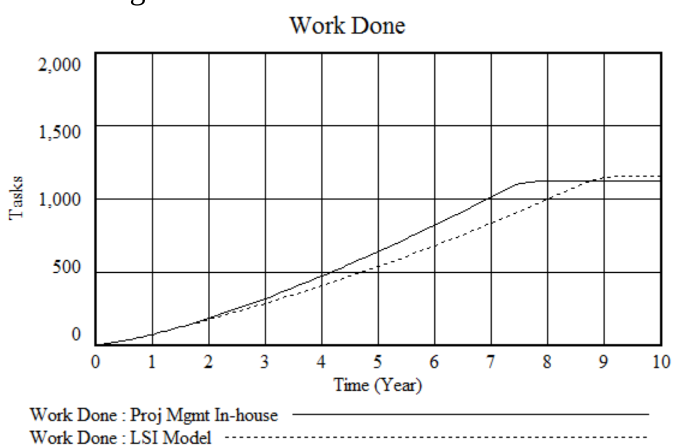

Figure 17: Comparison of Work Done for LSI and PMI Models

Figure 18 compares the undiscovered rework in the two models:

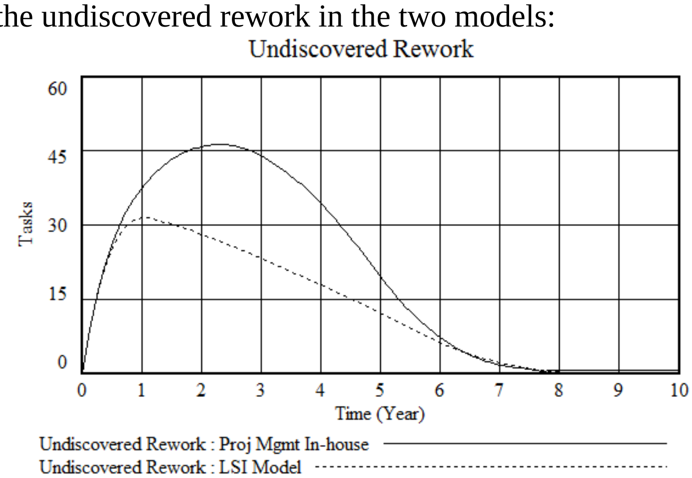

Figure 18: Comparison of Undiscovered Rework for LSI and PMI Models

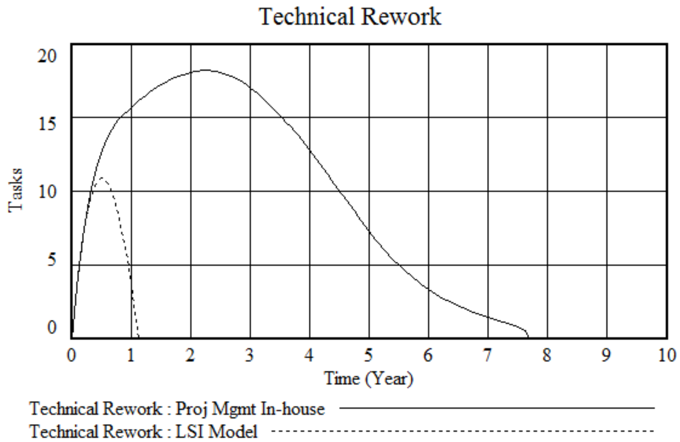

Figure 19: Comparison of Technical Rework for LSI and PMI Models

The undiscovered rework in the LSI model is significantly less than in the Project management in-house model. This is because the technical staff has the leisure to perform their tasks at their pace and as per our assumptions, staff working at their own pace produce no technical rework. Figure 19 demonstrates that the technical rework in the Project management in-house model could be high due to schedule pressure exerted over the staff in adhering to the schedule. Even though the rework is significantly higher in the project management in-house case, the project is better off than the LSI model (when the experience level of contractors is the same in both the models).

So, when is the Lead System Integrator Model better? And to what extent should the moral hazard be ignored?

Sensitivity Analysis

Variable	**LSI Model**	**Project Mgmt In-house**	**LSI Model Case-2**	**Project Mgmt In-house Case-2**	**LSI Model Case-3**	**Project Mgmt In-house Case-3**
Initial Experienced Staff	40	40	25	25	40	40
Initial Inexperienced Staff	10	10	25	25	10	10
Initial Estimated Time Given by Contractor	0.4 years	0.4 years	0.3 years	0.3 years	0.3 years	0.3 years
Control of Sponsor Over Project Execution	0	1	0	1	0	1

Table 1: Sensitivity Analysis

With the scenarios mentioned in the Table 1 above, Figure 20 represents the graph of work done comparison between the LSI Model Case 2, LSI Model and Project Management In-house scenarios.

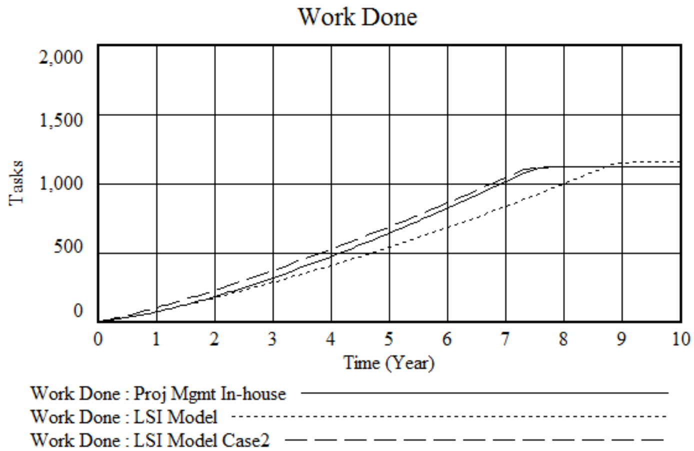

Figure 20: Work Done for LSI Model Case-2

In the LSI Model Case 2, although the Control of sponsor over project execution is 0, the project finishes before the other two scenarios. The factors contributing for this difference is that the initial estimated time given by contractor is 0.3, lesser than the other two scenarios; and the level of experience is significantly higher than the other two scenarios. In the Project Management In-house scenario, the sponsor would have control over the project execution, the productivity desired would be more than the current productivity as per experience and there would be cycles of rework as the staff is still newly hired, and cannot perform at the desired rate. Hence, between the two scenarios LSI Model Case 2 and Project Management In-house, the former is more efficient.

Figure 21 below is a simulation for Case 2 on LSI and Project Management In-house. With the reduced value of “Initial Estimates given by Contractor”, the difference in time taken to complete the project is very minimal. However, one key difference between the costs in the two models would be that the technical rework could be deducted from the billing hours of the contractor in the Project Management In-house model; as the sponsor has the transparency of the rework contributed by experience levels.

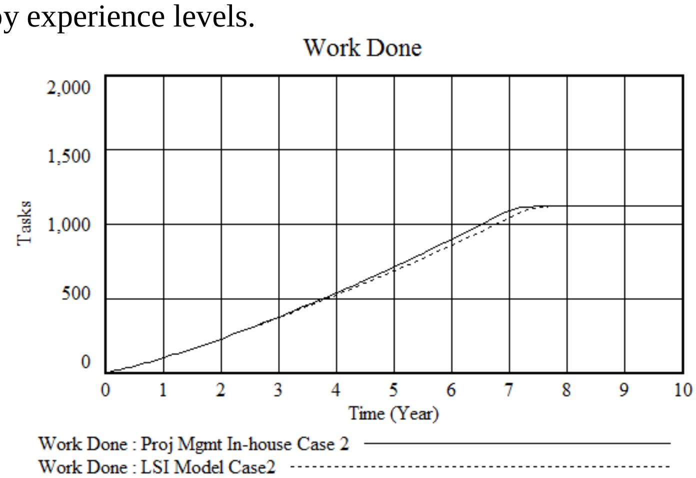

Figure 21: Comparison of Work Done for LSI Case-2 and PMI Case-2

Case-3 simulations for LSI and PMI models give similar results (see Figure 22):

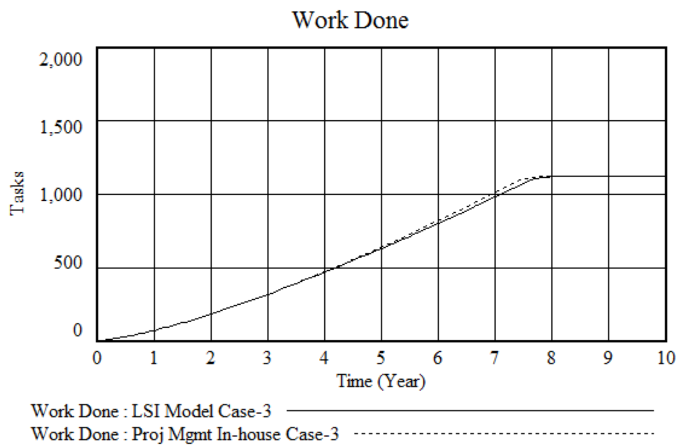

Figure 22: Comparison of Work Done for LSI Case-3 and PMI Case-3

Thus, the Initial Estimated Time Given by Contractor plays a crucial role. If the initial estimates are close to the actual, then there is no major difference between the LSI and Project Management In-house with all other parameters being the same; and with constraints in the model. However, with the Initial Estimates far from reality, it is better to have rework in the model, rather than striving for perfection at every task using the LSI model.

Conclusions from System Dynamics Model Experiments

If the initial estimates projected by contractor are unrealistic, then Project Management In-house will help adjust the productivity based on reality even if that incurs rework cycles. It becomes more desirable to exert schedule pressure on the contractor and after the rework is accounted, the project is still better off than the LSI model.

However, if there is a comparison between an LSI Model with initial estimates closer to reality and better experienced contractors v/s Project Management In-house Model with initial estimates buffered and inexperienced contractors: the LSI model would be better even if there is a small factor of moral hazard associated to it; as the moral hazard impact is much lesser than the rework impact from the PMI model with inexperienced contractors.

Thus, when evaluating bids, basing decisions on the lowest bid is not the best option. A detailed comparison of the estimates for RICE components, an approximate idea of the ERP experience level of the contractor employees, and credibility of the contractor could be some of the other factors crucial for consideration.

6. Discussion and Future Work

The work covered in this thesis has been primarily in evaluating the reasons for delay and cost overrun in ERP acquisitions, using the DOD cases studied as motivating examples. The system dynamics modeling of LSI versus Project Management in-house in this report has focused on two factors:

- Sponsor's control over Project Execution
- Impact of experience level of the contractor-staff

However, there could be additional factors that differentiate the two models – for example, impact of the integration activity between project sponsor and contractor, the length of the phases of implementation, frequency of product demonstration and end user feedback, availability of resources, turnover of leadership and personnel, and change rate of requirements and technology.

Government ERP implementation is significantly different from the commercial world; with external impacts such as changes in acquisition rules influencing the process of contractor selection and the length of increments in a project phase. The other levers which could impact the control of sponsor over the project are the way the contract terms are set - firm fixed price, cost-plus, or time and materials; and the impact of each of these on the contractor's incentives. The contract should also identify contingencies depending on the risks or uncertainties identified during the blue-printing stage.

All the arguments made and the levers discussed in the model have been assumed for a waterfall approach for system development with big design up front, followed by many years of implementation. The eNova case suggests an alternative, more manageable, Agile-like approach. Each phase took on a limited scope task that could be completed with small enough level of effort and a short enough time frame to be manageable. Each phase delivered a fully functional working product that demonstrated value before the next phase was initiated.

We anticipate building on the constructs in the current System Dynamics model to incorporate additional factors for ERP adoption and explore what happens to ERP systems as they age and as business needs and organization change.

7. References

Abdel-Hamid, T., & Madnick, S. (1991). *Software Project Dynamics: An Integrated Approach* (p. 288). Prentice Hall.

Beason, J. D. (U. S. A. F. (2000). The Need for Technical Warriors. *Aerospace Power Journal*. Retrieved May 17, 2012, from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj00/spr00/beason.htm

Bingi, P., Sharma, M. K., & Godla, J. K. (1999). Critical Issues Affecting an ERP Implementation. *Information Systems Management*, *16*(3), 7-14. Taylor & Francis.

Cooper, K. and Mullen, T. (1993), "Swords and Plowshares: The Rework Cycle of Defense and Commercial Software Development". *American Programmer* Vol 6, no. 5, (May 1993).

Deloitte Consulting. (1998). *ERP's Second Wave: Maximizing the Value of ERP-Enabled Processes*. *Business*. Retrieved from http://www.ctiforum.com/technology/CRM/wp01/download/erp2w.pdf

Eisenhardt, K. (1989). Agency Theory: An Assessment and Review. *The Academy of Management Review*, *14*(1), 57-74.

Haines, M. N., & Goodhue, D. L. (2003). ERP Implementations. *International Journal of Human-Computer Interaction*, *16*(1), 23-38.

Ketrick, P., Bailey, J., Cunningham, M., Odell, L., Douglas, G., Floyd, D., and Insolia, A. (2011). Assessment of DoD Enterprise Resource Planning Business Systems. Institute for Defense Analyses IDA Paper P-4691.

Kirsch, L. J. (1996). The management of complex tasks in organizations: Controlling the systems development process. Organization Science, 7(1), 1–21.

McKenna, N. A. (2005). Executing Major Projects through Contractors. *International Conference on System Dynamics 2005*.

Nah, F. F.., Lau, J. L.-S., & Kuang, J. (2001). Critical factors for successful implementation of enterprise systems. *Business Process Management Journal*, *7*(3), 285-296. Retrieved from http://www.emeraldinsight.com/10.1108/14637150110392782

Nah, F. F., Zuckweiler, K. M., & Lau, J. L.-shang. (2003). ERP Implementation : Chief Information Officers ' Perceptions of Critical Success Factors. *International Journal*, *16*(1), 5-22.

Neal, H. (2010). ERP Implementation Strategies – A Guide to ERP Implementation Methodology - Software Advice Articles. Retrieved May 6, 2012, from http://blog.softwareadvice.com/articles/manufacturing/erp-implementation-strategies-1031101/

Oracle (2008). What are RICE Components?. Retrieved April 23, 2012, from http://myoracleapplications.blogspot.com/2008/08/what-are-rice-components.html

Panorama Consulting Group. (2011). 2011 ERP Report. *Group*, 0-14.

Ross, J. W., & Vitale, M. R. (2000). The ERP Revolution: Surviving vs. Thriving. *Information Systems Frontiers*, 233-241.

Sapolsky, H. (2009) "Models for Governing Large Systems Projects", in Guy Ben-Ari and Pierre Chao (eds.) *Organizing for a Complex World: Developing Tomorrow's Defense and Net-Centric Systems*, Washington, DC: CSIS, p. 26

Snabe, J. H., Rosenberg, A., & Møller, C. (2008). *Business Process Management — the SAP ® Roadmap Contents at a Glance*. *Strategy* (p. 43).

Somers, T. M., & Nelson, K. (2001). The Impact of Critical Success Factors across the Stages of Enterprise Resource Planning Implementations. *Proceedings of the 34th Hawaii International Conference on System Sciences*, 1-10.

Somers, T. M., & Nelson, K. G. (2004). A taxonomy of players and activities across the ERP project life cycle. *Information & Management*, *41*(3), 257-278. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0378720603000235

Verville, J., Palanisamy, R., Bernadas, C., & Halingten, A. (2007). ERP Acquisition Planning: A Critical Dimension for Making the Right Choice. *Long Range Planning*, *40*(1), 45-63. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0024630107000088

Willcocks, L. P., & Sykes, R. (2000). The Role of the CIO and IT Function in ERP. *Communications of the ACM*, *43*(4).