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A BUSINESS PROCESS MODELING APPROACH FOR
EVALUATING A GOVERNMENT CONTRACT CLOSEOUT PROCESS

A Thesis
Presented for the
Masters of Science
Degree
The University of Tennessee, Knoxville

Clayton Jerrett Capizzi
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DEDICATION

This thesis is dedicated to my parents, David Capizzi and Stephanie Capizzi, for being great role models and friends, and my brother, David Capizzi II, and the rest of my family for always supporting me through all endeavors of life.

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ABSTRACT

This thesis examines the practice of Business Process Modeling (BPM) in the field of contracts management. Government defense contractors are heavily burdened by contracts which have ended, but have not been finalized and closed. In order to keep good relations with organizations regulating government contracts, contractors have been forced to devise a strategy to address contract closeouts. Through utilization of BPM practices, an organization is able to not only model the flow of their contract closeout process, but simulate the performance of their process under varying conditions so that goals and deadlines may be met. Data was collected about a defense contractor's contract closeout process, and a simulation model was created to mimic the behavior of the system over the time to complete the contract closeout process. Various levels of resources were used in simulating the process to test the performance and throughput of the system. Using simulation software, the closeout process was able to be successfully modeled under varying resource levels. The simulation models included true worker process times with integrated schedules, including holidays, over the expected period of performance. The simulation produced a realistic model which allows an organization to plan their resources to accomplish their contract closeout process under specified conditions and deadlines. This work also provides a base for further studies involving BPM and the field of contracts management.

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Abbreviations

ACO	Administrative Contracting Officer
ACRN	Accounting Classification Reference Number
BPM	Business Process Modeling
BPR	Business Process Reengineering
BPS	Business Process Simulation
CAC	Contract Audit Closing Statements
CACWS	Cumulative Allowable Cost Worksheets
CIMOSA	CIM Open System Architecture
CLIN	Contract Line Item
CPAF	Cost Plus Award Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee
CY	Calendar Year
DAR	Defense Acquisition Regulation
DC	Defense Contractor
DCAA	Defense Contract Audit Agency
DCMA	Defense Contract Management Agency
DEM	Deductive Enterprise Model
DFAS	Defense Finance and Accounting Service
DO	Delivery Order
DRID	Defense Reform Initiative Directive/Decision
EMF	Enterprise Modeling Framework
EPC	Event-driven Process Chain
FAR	Federal Acquisition Regulation
FY	Fiscal Year
GEM	Generic Enterprise Model
ICAM	Integrated Computer-Aided Manufacturing
IDEF	ICAM Definition
IEM	Integrated Enterprise Modeling
ISEC	Initiate Simulate Experiment Conclude
LAI	Lean Aerospace Initiative
LC	Learning Curve
LEM	Lean Enterprise Model
LESAT	Lean Enterprise Self Assessment Tool
L-H	Labor Hours
LOE	Level of Effort
MDSI	MOCAS Data Sharing Initiative
MIT	Massachusetts Institute of Technology
MOCAS	Mechanization of Contract Administration Services

OMB	Office of Management and Budget
OPR	Office of Primary Responsibility
PCO	Procuring Contracting Officer
PERA	The Perdue Enterprise Reference Architecture
POP	Period of Performance
PO	Purchase Order
RIT	Rapid Improvement Team
SME	Subject Matter Expert
SPO	Systems Program/Project Office
T & M	Time and Materials
TOVE	Toronto Virtual Enterprise
UML	Unified Modeling Language
VECP	Value Engineering Change Proposal
VSM	Value Stream Mapping
WFM	Workflow Management

Chapter I

Introduction

Closing contracts is a subject that every government contractor must address. Thousands of physically complete contracts have accumulated among defense contractors over the past decades, yet remained open because closeouts were a low priority. Recently the federal government has begun to stringently enforce policies and procedures for contract closeouts, forcing government contractors to comply with all rules and complete contracts within specific timelines. Specially, FAR 4.801-1 which sets time standards for closing out contract files (Moser & Arviso, 2007). Now that the time standards are being enforced they have suddenly become priority to contractors. Before delving deeper into this subject, a description of the general requirements of a contract closeout will be given.

1.1 Government Contract Closeouts Overview

Government contract closeout completion is when “all administrative actions have been completed, all disputes settled, and final payment has been made.” (Guidebook: Contract Closeout, 2009) The procedure is led by the Administrative Contracting Officer (ACO) from the Defense Contract Management Agency (DCMA). The ACO coordinates activities between the contractor, Defense Contract Audit Agency (DCAA), Defense Finance and Accounting Services (DFAS), and any other pertinent agencies, according to the contract. Policies and procedures in which DCMA follows are dictated by the Federal Acquisition Regulation (FAR). Instructions on

how to properly close a contract is detailed in FAR 4.804. A list of generalized tasks of typical contract closeout actions is given below.

- Review contract data and confirm all deliveries accepted
- Identify and deobligate excess funds
- Complete any price revisions
- Ensure all subcontracts are settled by the prime contractor
- Indirect costs are settled
- No outstanding value engineering change proposals (VECP)
- Final patent report is cleared
- Final royalty report is cleared
- Dispose of Government Property
- Dispose of classified documents
- Termination docket is completed
- Contractor's final closing statement is completed
- Contractor's final invoice has been submitted
- Contract audit is completed
- Deobligate funds: deobligation of excess funds is one of the contract administration functions normally delegated to the Administrative Contracting Officer (ACO) at the Contract Management Office (CMO).

The generalized tasks can be specifically broken into four or five major steps for closing a contract. First, a contract must be reviewed to see if it meets the requirements to begin closeout procedures. This step can commence once the contract's physical life is completed. The next step is to begin any specialized contract procedures. These specialized closeout activities are stated in the original contract, and often include indirect cost settlement, reconciliation/deobligation of funds, release/return of materials, and quick closeout initialization, which will be discussed later.

With the authorization of the ACO, a contractor may perform a Quick Closeout, FAR 42.708, in which indirect cost rates are settled with the contracting officer before final indirect cost rates are determined. Quick closeouts do have restrictions to the size and type of contract, but are effective in saving a contractor time, money, and resources.

The third step is to ensure that all contracted actions have been completed, and the final payment has been made. Before the final voucher is created for this step, contract documents are reviewed to ensure correct billing information follows the base contract. Once all administrative actions for the contract to be closed have been fully and suitably completed, a Contract Completion Statement is issued to the Procuring Contracting Officer (contracting agency), which in essence "closes" the contract. Oftentimes there is an additional step involved with closeout procedure. Issues such as specialty property issues, specialty payment issues, patent/royalty issues, and similar administrative issues are addressed here. A contract closeout

checklist is a common way to ensure that these issues have been correctly addressed and completed. Though quick closeouts seem to be the logical path for a company to take, the government does not always permit the use of this technique. This is why for this thesis quick closeouts will not be considered in this thesis. The general approach to contract closeouts is summarized in Figure 1.1.

1.2 Difficulties with Government Contract Closeouts

A large portion of government contracts which are facing approaching deadlines to close contracts are defense contractors. For many years these defense contractors would put their main focus on receiving the contract award and physically performing the contract, but not closing the contract. Since these companies did not stress closing contracts, the government agencies regulating this area, DCMA and DCAA, decided to crackdown, and put a deadline to when these contracts must be closed. This means a company could potentially lose millions of dollars if these contracts are not properly closed.

Another problem which has arisen out of the government pressure is the contracts acquired through company buy-outs. Many of the larger defense contractors would buy smaller companies or merge with another company, thus acquiring the other company's awarded contracts. During these mergers and buy-outs, contract information was oftentimes lost in transit, misplaced, mislabeled, or workers with knowledge about contracts retired or were

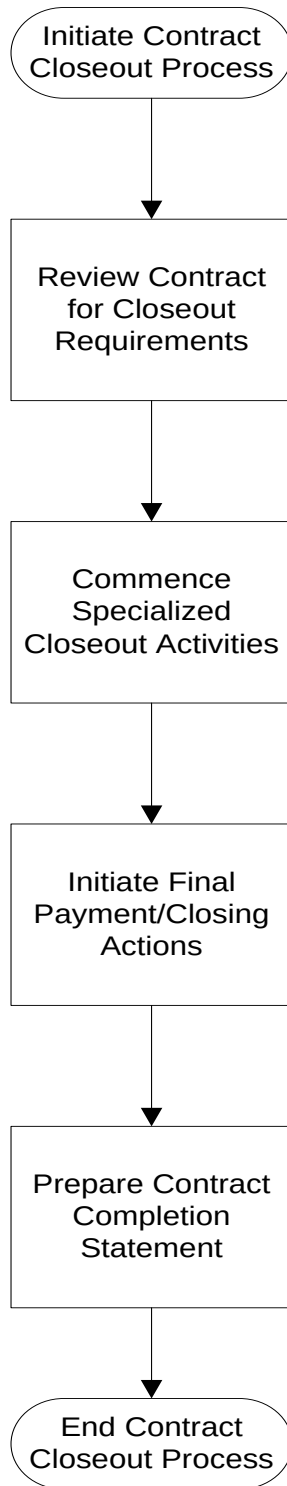


Figure 1. 1: Generalized Contract Closeout Process

fired. Some closeout contracts ended nearly 20 years ago which is now a big challenge to these contractors. Core information required to closeout contracts cannot be retrieved, preventing contracts from being able to be closed, thus straining relationships between defense contractors and their ACOs.

A large degree of the difficulty in closeouts stems from the how the contracts are structured, and the diverse types and sizes of contracts. Common types of government contracts include Cost Plus Fixed Fee (CPFF), Cost Plus Award Fee (CPAF), Cost Plus Incentive Fee (CPIF), Labor Hours (L-H), Time and Materials (T&M), and Level of Effort (LOE). Funding on these contracts can also range from a few thousand dollars to millions of dollars. Many also include special stipulations to how tasks are to be performed or costs to be broken up. The larger contracts, which span over many years, the base contract is broken up into Delivery Orders (DO), which have a Period of Performance (POP), contract length, within the base contract POP.

1.3 Addressing Contract Closeouts

A large number of defense contractors have formed contract closeout teams internally to specifically work on closing out physically complete contracts. These teams usually consist of persons in finance and contracts backgrounds with varying degrees of expertise knowledge. Instead of viewing contract closeouts as a process, it can more suitably be approached as a project. The goal of the project is to close out the backlogged contracts which have accumulated over the past few years. Any contracts that have recently become physically

complete will be handled by the assigned contracts administrator. To put it more in perspective there is a known, finite amount of contracts being closed in this process. By linking industrial engineering principles with the subject matter experts (SMEs) on contracts, contract closeout teams can effectively plan and accomplish their goal.

Common tasks across the board for contract closeout teams are researching contracts and modifications in order to populate contract information, generating and verifying cost models, creating final billing, and completing any other administrative tasks specific to their contract. The deadlines for submission to DCAA review are given to the contractor by their ACO, usually grouping contracts together by the year in which they are physically complete. Once submitted, DCAA reviews the closeout to ensure that all cost models and contracted activities are correctly completed and valid. Often, changes must be made after submission by the contractor in order for the closeout to be accepted.

1.4 Scope of Work

Company DC (Defense Contractor) is a defense contractor that is faced with the loss of millions of dollars in previously completed government defense contracts if the closeouts are not completed by certain deadlines. Over the past few months company DC has several times had to restructure their closeout process in order to try and improve their progress on their ever growing list of contracts to close. Throughout this time period, new team members have been added and sub-processes have been changed in order to accommodate the process. Though

the process has been changed in order to make it more efficient, contracts have still failed to be closed, and DCAA deadlines to close contracts have drawn closer. Through the use of simulation and business process modeling/reengineering (BPM/BPR) of company DC's contract closeout process, a more efficient process can be developed. This will be accomplished through studying the processes involved with contract closeouts and creating a simulation, interviewing company DC employees, examining several BPM/BPR methodologies, and implementing and measuring improvements into the base model. From this research a comprehensive list of improvements can be suggested in order to improve the performance of the closeout process, and ultimately meet DCAA deadlines.

1.5 Summary of Introduction and Purpose

It is apparent that contract closeouts are an important focus of many defense contractors, and are vital to maintaining good government relationships. The purpose of this thesis is to add to the contract closeout body of knowledge in both applied and scholarly areas:

Applied

- Create a descriptive model and planning tool to aid in resource planning for the contracts closeout process.
- Develop the underlying principles for strategic revisions within the contract closeout process.

Scholarly

- Adapt business process modeling (BPM) principles and methodology to the contracts industry.

- Queuing theory principles with the use of simulation.

This thesis is organized as follows. The next chapter will be a literature review, Chapter III will discuss the modeling approach, Chapter IV will contain the results of the simulation model, and Chapter V will provide any conclusions about the model and future recommendations.

Chapter II

Literature Review

In a May 2007 article in *Contract Management Magazine* (Moser and Arviso, 2007), an emphasis is put on the importance of closing complete contracts in a contracting organization. They outline many of the important FAR clauses, which regulate closeout procedure, and what contributes to a successful contract closeout process. The important FAR clauses which are outlined in this article highlights quick-closeout procedures, allowable costs, time standards, and what triggers a contract closeout. The message that is being emphasized in this article is that an effective contract closeout process requires extensive knowledge about FAR clauses and procedures, solid communication between the contractor and the government, and a strong contract closeout team dynamic.

Jay W. Forrester (1961) centralized many of the theories and principles underlying the modeling of industrial systems in his book *Industrial Dynamics*. When describing models of industrial systems, Forrester expressed the importance of how mathematical models must be dynamic, address business fluctuations, and uncertainty in the system. Mathematical models are only useful when the model fully explains the real system and is able to predict future conditions. Any vagueness must be eliminated, or else the model cannot be validated. The true value of a mathematical model is derived from the precision of the model, not the accuracy.

Forrester outlines the development of a scientific method for process improvement for which he refers to as the “Steps in Enterprise Design.” The steps are as follows:

- The Goals
- The Description of the Situation
- The Mathematical Model
- Simulation
- Interpretation
- System Revision
- Repeated Experimentation

This methodology gives a detailed step by step approach into how managers can implement industrial dynamics principles into the improvement of their systems, which was a new concept. Forrester’s methodology was used as the basic template for the approach in this thesis.

Forrester states that the “validity (or significance) of a model should be judged by its suitability for a particular purpose.” This point is important because models are often extended past their initial focus, which can produce false or misleading results. Keeping in mind the objective of the model throughout the modeling and evaluation process is vital to success. Better put, “The value of the objective transcends all other considerations in determining the utility of a model.”

Industrial Dynamics lays much of the ground work for industrial process and system improvement principles and methodology which are still used today.

Gladwin and Tumay (1994) examined how simulation modeling could be used in Business Process Reengineering (BPR) to improve financial, human resource, and production components of a business. They found that through use of flowchart models, a service process can be simulated capturing important process, resource, and entity performance data. From this model and data, improvements can be implemented to decrease backlogged processes, maximize resource capabilities, and reduce costs. Their research also studied the relationships between capacity, human factors, time in process, and staffing levels in the course of simulation. They determined that simulation models can take into account realities of modern business processes, such as variability, uncertainty, and interdependency of resources.

In 1995, Jablonski traced the links between workflow management and business process modeling, and how their interrelation could benefit each other. He notes how Workflow Management (WFM) could provide a suitable infrastructure for the business process modeling/reengineering (BPM/BPR). Jablonski then creates a development methodology for Workflow Management Systems from a systems engineering lifecycle model. This methodology integrates business process modeling with WFM systems, providing a much more flexible model for an organization. Through use of meta-models and analysis the BPM and WFM system are integrated for a mutually beneficial model. A major benefit of the new methodology was how the business process model reflected and reacted to changes in the real-world business environment. The approach as a whole demonstrates the potential benefits in

linking business process modeling and workflow structures in order to encourage improvements within an organization.

Heinl et al. (1999) examine the flexibility in workflow management systems and many of the difficulties that arise when developing such a model. In order to better model real world applications in workflow management, they developed a classification scheme for flexibility for system approach. This scheme allows the user to customize a workflow design to fit their specific system platform, and takes two approaches to flexibility: flexibility by selection and flexibility by adaptation. Flexibility by selection allows a user to offer multiple execution paths within a workflow, while flexibility by adaptation focuses around adapting to uncertain or unknown execution paths. Since this was a new approach to flexibility in workflow management they noted that the work in this area is not complete. They concluded that a flexible workflow management application must include both approaches to flexibility to cover the complexity and uncertainty that workflow models encompass.

Paul, Giaglis, and Hlupic (1999) discussed the considerations that must be undertaken for discrete event simulation in business processes. A business process model must be hierarchically decomposing an organization, so that all perspectives are taken into account. The data collection for business models can be difficult to collect and properly capture, but is important to the validity of a model. To properly capture the BPS feel that both technical and political requirements of a model must be fulfilled. Technical requirements deal with the

structure and use of the model, and political requirements communicating relationships and meaningful information to the user/management. Paul et al. feel that BPS is a powerful tool for businesses to implement, though many complexities and difficulties exist in accurately capturing business processes, and there are large gaps of research in simulation and business process analysis missing.

In another paper, Giaglis, Paul, and Hlupic (1999) developed a methodology for business process simulation, based upon generic simulation methodologies and generic approaches to business change management. They discussed the many issues and considerations that must be undertaken in BPS to ensure that a model is valid and useful to an organization. The referred to as the ISEC methodology is focused around four phases: Initiate, Simulate, Experiment, and Conclude. This methodology is not a sequential method, but rather consists of iterations of some of the phases until the model is refined and desired results are met. Giaglis et al. again mention the complexities of organizational processes, and the analysis of such systems can bring about difficulties relating to data collection, experimental design, and multi-perspective model analysis. They also do talk about how the area of BPS is in its infancy, and how BPS is relatively unknown or untested by many organizations that are missing out on huge potential benefits.

Fox and Guninger (1998) talked about the important role of enterprise models in creating a competitive and adaptable organizational structure. A strong enterprise model can allow an

organization to quickly react and adapt to changing market and customer demands. They mention the lack of a basic enterprise model template that organizations can follow instead of developing an enterprise model themselves. Fox and Guninger propose a Generic Enterprise Model (GEM), which provides an organization with the basic building blocks of an enterprise model and allows them to adapt and customized the model to their specific organization. A GEM allows different parts of organizations to better understand functions and capabilities. Many of the enterprise model approaches that were current to the time, such as IDEF, PERA, and Enterprise-wide Data Modeling were evaluated, and proven not to meet the criteria of a widely-applicable enterprise model. They then discuss the more recent developments with Deductive Enterprise Models (DEM). DEMs, such as the Toronto Virtual Enterprise (TOVE), have started to play an increasingly larger role in enterprise modeling by using deductive knowledge, so that the models functionality is appropriate to the situation. Further development of DEMs has the potential to more accurately model enterprises and their functionality.

Kamath et al. (2001) give a comparative evaluation of several enterprise process-modeling techniques, which include IDEF (ICAM Definition), CIMOSA (CIM Open System Architecture), PERA (The Perdue Enterprise Reference Architecture), IEM (Integrated Enterprise Modeling), EPC (Event-driven Process Chain), and TOVE (Toronto Virtual Enterprise). From these six enterprise modeling techniques, they determined certain characteristics that an enterprise model should include. A conceptual model for a new enterprise modeling framework was then developed which outlined the necessary features of a comprehensive enterprise model. They

conclude that a number of good approaches to enterprise modeling do exist, but most lack the ability to accurately implement and measure changes to an enterprise.

Srinivasan and Jayaraman (1997) examined the integration of Enterprise Modeling Framework (EMF) with discrete-event simulation. EMF methodology requires an understanding of the functions, information, and dynamics of an enterprise. They explain how EMF links enterprise modeling with simulation, with the goal of process understanding and improvement. They give the example of an apparel manufacturer, and how a model of their enterprise operations can be modeled and simulated. Srinivasan and Jayaraman also mention the SIMAN code, commonly used in simulation software, which is the simulation backing code generated upon entering a model logic flow and its parameters. The conclusion is that EMF offers an enterprise an easier method of simulation than was previously available, and that the model developed accurately captures enterprise behavior, so that it can be used in planning and decision-making with confidence.

De Vreede et al. (2003) bridged the conceptualization and simulation of business processes through the utilization of Rockwell Arena Simulation software. They discuss how mapping businesses processes from a conceptual model to a simulation model present many difficulties, and will not always translate accurately. A set of functional and generic requirements for a simulation building block library was then determined so that business processes can be properly translated from a conceptual to an empirical model. The Arena Professional Edition

was used to create business process simulation template since it met all functionality and generic requirements. The Arena simulation environment provides the potential for robust business process models with flexible functionality to be created and evaluated with relative ease compared to earlier methods. De Vreede et al. concluded that the template created in Arena facilitates better translation from conceptual model to simulation model.

Wynn et al. (2008) sought to develop a modeling architecture which addresses already in-use processes, as opposed to processes not yet implemented, in order to determine optimal process operation. They outline the shortcomings of many simulation tools, like the inability to set multiple completion horizons in the short-term. The developed simulation architecture allows multiple simulation states to be added to the “base” simulation, so that multiple scenarios can be simulated and analyzed. Historical data from the simulations is logged and “fed” back into the system as a reflection of true processing behavior, instead of a constant processing behavior. In order for the simulation of the system to produce accurate, short-term operating predictions and behavior, the initial operational behavior must reflect recent historical data. Wynn et al. concluded that it is possible to produce a simulation which can reflect current processing conditions, and can be used to support operational decision-making.

Mendling and Strembeck (2008) challenge the understandability of models as opposed to the quality of models. They argue that business process modeling has been successfully implemented over the past few decades, but little is known about how models work, and what

makes a “good” model. There is a large body of knowledge concerning the analysis and validation of the models, but the amount of human understandability is minimal. Their contribution deals with the understandability of three factors: human, structural, and textual (content). A survey was given to participants to analyze their understanding of six different models. They concluded that the three factors of interest, human, structural, and textual, did impact the understandability of the models on different levels. This should push organizations to better train and educate their employees on modeling structures and labels, and to also produce some type of standardized modeling guidelines.

Lightfoot (2006) iterated the importance of the use of BPM and simulation in the defense contract industry, but was perplexed why standards for modeling do not exist. He goes over the specific requirements for developing an automated business simulation, and the need for a Unified Modeling Language (UML) so that models can be transferable across different programs. Much of the technology is already developed; it is simply a matter of properly putting it into practice in the defense contract industry.

Zangwill and Kantor (1998) discussed the use of learning curves in the realm of continuous process improvement. The journal article talks about how learning curves are used to track improvements in processes, but the two concepts are not well defined or quantifiable. They theorize methods to how the management of an organization can monitor improvement and learning over incremental periods of time. Through development of a differential equation

which characterizes continuous improvement and learning, they provided a base for how management could evaluate improvement procedures more effectively and quickly. Through further development and study of their theory of continuous improvement and learning, they hope to create a more effective manner measuring improvement by management.

Rebentisch and Jobo (2004), as part of the Lean Aerospace Initiative (LAI), sought to Lean implementation into government operations. The specific programs/processes which were selected were the F/A-22 Test and Evaluation process, the F-16 Contract Closeout process, and the Global Hawk Evolutionary Acquisition processes. The LAI, which is backed by the Massachusetts Institute of Technology (MIT), brought together various knowledge and tools with government and Lean Subject Matter Experts (SME) in order to facilitate this Lean implementation. For each process/program they planned to implement Lean in three phases: (1) Set-up phase, (2) Planning phase, and (3) Execution phase. The goals of the F/A-22 program were to meet costs, schedule, and performance expectations, which were met or exceeded with great success. Global Hawk goals were to reduce cost and lead time of subsystems, which was met and is continuously improving, as the project is ongoing, through the use of Value Stream Mapping (VSM). The F-16 Contract Closeout process heavily focused on inactive contracts, which have passed their POP. Twelve significant initiatives have been identified to improve this process, such as establishing a single DFAS point-of-contact for a contract and automating the work order generation process for contracts undergoing the annual audit

phase. These improvements to the Contract Closeout process significantly reduced cost and the estimated cycle time of the process from three to seven years.

Chapter III

The Model

Developing the contract closeout model was not a simple undertaking. This involves translation of previously undefined processes and logic into mathematical representations. Business process modeling (BPM) facilitates this smooth transition from the idea of a process to a physical representation. To effectively capture the process logic and flow, I utilized the “Steps in Enterprise Design” methodology (Forrester, 1961) for developing my model. Forrester’s methodology follows the structure:

- The Goals
- The Description of the Situation
- The Mathematical Model
- Simulation
- Interpretation
- System Revision
- Repeated Experimentation

I will develop the first 4 steps of Forrester’s methodology in this chapter, and then address interpretation in Chapter IV, and the final two steps of system revision and repeated experimentation in the conclusion of this thesis. This methodology will yield a highly robust model capable of mimicking the true behavior of company DC’s contract closeout process. By

studying the performance of the model with simulation, improvements may be implemented to the process under varying conditions.

3.1 Defining the Goal

When developing a model it is necessary that a goal or focal point of the model development be defined at the beginning. By defining the scope of the model the focus of the effort will not skew from the original model intentions. The goal of this effort is to develop a model which accurately reflects company DC's contract closeout process. This model can then be used to identify key areas of improvement, and aid in resource planning and process timeline.

The purpose of using simulation in modeling is to capture some desired performance measures about a process in order to draw conclusions. Key areas of interest for Company DC's contract closeout process is resource utilization, the average amount of time to process a contract closeout, and how long will it take to complete the entire process. Resources' utilization and average processing times for closeout packets are included on the typical summary report, but capturing the process length was difficult because it varied in every replication.

3.2 Data Collection

To collect information about the contract closeout process I conducted interviews with company DC's contract closeout employees. Appendix A is the questionnaire supplied to each

closeout worker to gain a better perspective in the type and length of tasks they are performing. The questionnaire also identifies other characteristics of the process, such as the amount and type of contracts entering the process. This process is interesting because it includes three types of contracts. A summary of the different types of contracts and amount associated with each is located in Table 3.1.

The logic flow of the contract closeout process was developed in close collaboration with the Project Leader. Several iterations of the process logic flow were created and revised until an accurate and complete logic flow was created.

3.3 Process Description

To better understand a process it is important to know the key players and components involved in the process, which is summarized in Table 3.2. By identifying the major components (inputs, processes, outputs, stakeholders) of the process, the purpose and justification for the model can be determined. The contract closeout model is of primary use to company DC in improving their process, but a secondary stakeholder whom can benefit is DCAA, since they are directly involved with receiving closed contracts.

Table 3. 1: Contract Type and Amount Summary

Contract Type	Number of Contracts
Department of Defense	242
Non-Department of Defense	200
Subcontracts	200

Table 3. 2: Summary of Process

Inputs	Processes	Outputs	Stakeholders
-Physically Complete Contracts -Government Regulations	-Contract Closeout Process, refer to Figure 3.1	-Closed Contracts -Settled Expenses (Revenue)	-Company DC -DCAA/ Government

The justification for process improvement can be quantified in two ways:

- The first being that the greater the throughput of closed contracts by company DC, the quicker they are paid by the government.
- The second way is that the greater the throughput of closed contracts will increase the goodwill and relationship between company DC and the government. This comes in handy when company DC has proposals and follow-on work at stake with the government.

The throughput can be directly related to the amount of strategic resources in company DC's contract closeout process, in particular the Workers, which will be described in section 3.5.

With an increased amount of resources there is a tradeoff between the cost to add a resource and the amount of time in which the process finish time will improve. This is often difficult to forecast, but by utilizing a simulation model, company DC will be able to better quantify this relationship and determine the optimum level of Workers to complete the contract closeout process over an acceptable time horizon.

3.4 Assumptions

No process can be completely accurate when it is translated into a mathematical model/representation, so it is important to have a set of assumptions. These assumptions act as a set of conditions in which the process will perform under. Company DC's contract closeout process took on the following assumptions in translating the process into a model:

- All workers will be completely dedicated to this process. This means there is no shared time with activities outside of this process.
- There are three types of contracts being processed, but are treated the same.
 - Department of Defense (DOD) contracts
 - Non-Department of Defense (non-DOD) contracts
 - Subcontracts
- Administrative activities, such as weekly closeout meetings, are integrated into process times.
- There is no set time limit to complete the contracts. The model will terminate once all contracts (Department of Defense, non-Department of Defense, subcontracts) have been fully processed.
- The amount of the employees work is based off of a 5-day work week
- Holidays
 - Scheduled holidays were determined by the work holidays received by the Federal Government:
 - Martin Luther King Day (Third Monday in January)

- Memorial Day (Last Monday in May)
 - Independence Day (July 4th)
 - Labor Day (First Monday in September)
 - Thanksgiving Holiday (Fourth Thursday in November plus the day after)
 - Winter Holiday (December 24th and 25th)
 - New Year's Holiday (December 30th – January 1st)
- All Accounts Payable/Receivable documentation is generated before the process is initiated.
 - Weekly contract closeout team meeting time will be assumed to be included in process times.
 - There will be no catastrophic events which will cause delays to the contract closeout process.
 - All contract closeouts follow the same process distributions.
 - The CFO approves 90% of all contract closeouts.
 - All auditor questions are addressed only by the Project Leader.
 - A new employee will become experienced after handling three contract closeout packets.

3.5 Model Description

The model of the contract closeout process can be used to study the relationships that occur between the resources and sub-processes. In this sense queuing theory can be employed to

help observe the delays or hold-ups in the processing of contracts. Since this process is finite, not continuous, observations about queue lengths of the sub-processes must carefully be considered. A large number of entities will remain in the queue at the beginning of the process since the number of entities entering the process is known. Modeling of process under various resource levels will allow identification of the best-case process scenario by observing a mixture of the process performance measures, such as scheduled utilization, work-in-process, and process throughput.

The model takes into account extended processing time which occurs with new workers. Though this might seem like a learning curve it is more of a worker assimilation rate. Learning curves typically can identify exact processing times for a specific unit, while the sub-processes being modeled follow a process distribution, not a uniform process time. The assimilation rate takes into account the basic principle that a new worker will take a little longer to initial process a contract closeout due to unfamiliarity. Once the new worker has assimilated to the process, he or she will process at the same speed as an experienced worker. The assimilation rate is a uniform, flat-rate of processing three contract closeouts, which was suggested by company DC based on experience and estimation, as opposed to learning curves which typically follow an exponential distribution. Finally, in order to effectively capture a learning curve there must be an adequate population in which to gather data, which is not available in this study.

Within the contract closeout process, the process can be further broken down into resources and sub-processes. Identification of these components and their functions allows for effective process analysis and improvement strategies.

3.5.1 Resources

- Worker: A contracts/finance department employee dedicated to generating contract closeout packets and documentation. Once these workers initially process closeout packets, the worker will perform all reworks on that packet. Referred to as experienced workers or new workers.
- Project Leader: Leader of the contract closeout team whose responsibilities include conducting meetings, performing closeout packet reviews, and answering auditor questions.
- Compliance Worker: A compliance department employee whom reviews closeout packets to ensure they comply with all government and in-house policies and procedures.
- Legal: A lawyer from the legal department who signs any required legal documentation for the closeout packet.
- Chief Financial Officer (CFO): The head of the organization's finance department whom reviews the closeout packets for completion and correctness. He ultimately signs the documentation required to finalize a closeout packet before submission to DCAA auditors.

3.5.2 Sub-Process Descriptions

- Week 1 and 2 Tasks: Contract files are found and reviewed, a contract brief is created, and cost models are generated by an experienced worker.
- Learning Curve (Assimilation Rate) Week 1 and 2 Tasks: Contract files are found and reviewed, a contract brief is created, and cost models are generated, except at a slower pace than experienced workers.
- Week 1 and 2 Tasks No More Learning Curve (Assimilation Rate): Contract files are found and reviewed, a contract brief is created, and cost models are generated by worker who was a new employee, but is now experienced.
- Project Leader Review: The closeout packet is reviewed and marked up for revisions/corrections.
- Rework: Any revisions/corrections are made to the closeout packet by the original worker assigned to the closeout packet.
- Compliance Review: The closeout packet is reviewed and marked up for revisions/corrections by a worker from the Compliance department.
- Compliance Rework: Any revisions/corrections are made to the closeout packet by the original worker assigned to the closeout packet.
- Legal Review: Legal documentation is filled out.
- CFO Review: The Chief Financial Officer reviews the closeout packet for correctness and completeness.

- Address Auditor Questions: Any questions about a contract closeout packet are addressed by the Project Leader. Though the contract closeout packet has technically left the closeout process, it still remains under audit by DCAA.

The sub-processes listed above comprise the entire contract closeout process. Located in Table 3.3 is a summary of the mathematical distributions and resources which correspond to each sub-process.

A varying number of mathematical distributions were used to describe the processes due to varying process behaviors. The distribution which was used the most was the triangular distribution. This distribution allowed the minimum, mean, and maximum process times to be captured, rather than a uniform range. Tasks, such as a legal review, utilized a constant time value since the task of signing forms was predictable over the long run.

3.5.3 Model Logic Flow

A model logic flow allows for visualization of the basic process flow, while also providing a basis for translating the model into simulation software. As previously mentioned the logic flow for company DC's contract closeout process was developed in close collaboration with the project leader of the process. The process begins with all of the contracts (DOD, non-DOD, and Subcontracts) waiting in a queue to receive their initial processing, which I refer to as the processes as "Week 1 and 2 Tasks" and "Learning Curve Week 1 and 2 Tasks." The key

Table 3.3: Summary of Closeout Processes

Process	Mathematical Distribution	Minimum	Mean	Maximum	Units	Resources
Week 1 and 2 Tasks	Triangular	36	45	58.5	Hours	Workers
Learning Curve Week 1 and 2 Tasks	Triangular	54	72	90	Hours	Workers
Week 1 and 2 Tasks No More Learning Curve	Triangular	36	45	58.5	Hours	Workers
Project Leader Review	Constant	N/A	4	N/A	Hours	Project Leader
Rework	Uniform	2	N/A	3	Hours	Workers
Compliance Review 1 & 2	Uniform	2	N/A	3.5	Hours	Compliance Workers
Compliance Rework	Triangular	3	4.5	6.5	Hours	Workers
Legal Review	Constant	N/A	1	N/A	Hours	Legal
CFO Review	Triangular	0.75	1.5	2.5	Hours	CFO
Address Auditor Questions	Triangular	0.5	1.5	2.5	Hours	Project Leader

difference between the two tasks is that the contract closeouts assigned to “Learning Curve Week 1 and 2 Tasks” will take slightly longer to process than “Week 1 and 2 Tasks” to complete since a new, inexperienced worker is assigned to the closeout. After processing a total of 3 contract closeouts the inexperienced worker becomes experienced and the process then becomes “Week 1 and 2 Tasks No More Learning Curve.” Once the new worker becomes experienced, he or she takes on the same processing time. This amount of contracts was suggested by company DC. It should be noted that throughout the process the worker who initially processes the contract closeout packet will be assigned to for the entirety of the process. That means anytime the closeout packet must be reworked, the worker who processed the “Week 1 and 2 Tasks” will process the rework.

The contract closeout packets are next reviewed by the project leader then sent back to the initial employee for rework. The contract closeout packet which has been reviewed by the project leader takes on a higher priority than the “Week 1 and 2 Tasks”, so the worker must stop work on “Week 1 and 2 Tasks” in order to “Rework” the higher priority contract closeout packets. Once there are no more closeout packets to review, the worker can return to processing “Week 1 and 2 Tasks.”

Once corrections are made in the “Rework” process, closeout packets are then sent to the Compliance Department for the “Compliance Review” by one of two compliance workers.

Again, once closeouts have been processed by the compliance department more rework and revisions must be done on the closeout packet in the “Compliance Rework” process. This process again utilizes the initial workers and the priority now supersedes any other processes utilizing the initial workers. Again, when there cease to be an more closeout packets in the “Compliance Rework” queue, the worker defaults to working on the “Rework” process first and if there is no work to be done, the worker returns to “Week 1 and 2 Tasks.”

Closeout packets next move through the “Legal Review,” which is a quick process mainly consisting of legal documentation being assembled for the closeout packet. Legal then passes the closeout packet to the Chief Financial Officer (CFO) for the “CFO Review.” Ninety percent of contract closeouts are approved by the CFO and move onto the next phase, while ten percent are reject and sent by for corrections. The corrections are completed in “Compliance Rework” process, and then must again undergo “Legal Review” and “CFO Review.” This is realistic because depending on the type of changes made to the closeout packet, the legal documentation might change, and the CFO must approve of the contract closeout before it is sent off to DCAA for auditing.

After the CFO approves the contract closeout packet and signs off on the paperwork, the closeout packet is then audited by DCAA and any questions about the closeout packet are addressed the project leader. This final process is named “Address Auditor Questions.”

Since there is dual utilization of the project leader between “Address Auditor Questions” and “Leader Review” processes, the work priority is given to the “Address Auditor Questions” process. Once a contract closeout exits the “Address Auditor Questions” process they leave the system, and are considered to be accepted by DCAA. Figure 3.1 is a representation of the logic flow as described above.

3.6 Simulation Software Selection

Rockwell Arena Version 12.0 was the software used to model and simulate company DC’s contract closeout process. The Arena software provides a flexible platform for which a wide variety of processes may be developed. This software has applications in manufacturing, supply chain, and military/defense operations. Models are developed through a number of logic building blocks. Complex model logic can be developed through careful manipulation of the building blocks. Arena allows the mathematical model to be inherently captured when building the process and logic flow through the Arena software code. The simulation aspect of the software allows a user to manipulate models through implementation of schedules, historical data, and animation. Arena gathers general performance statistics about the simulated model, as well as allowing users to customize performance measures.

The Arena software package also has add-ons such as the input analyzer and OptQuest function which allow for further analysis of a model. The input analyzer allows a user to

Company DC's Contract Closeout Process

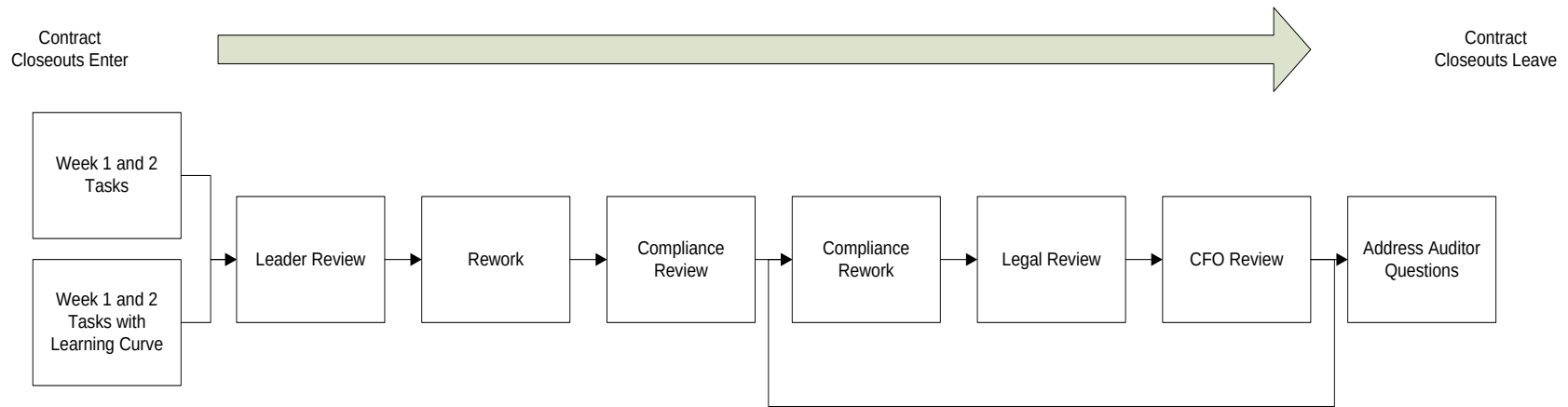


Figure 3. 1: Model Logic Flow

input a set of data, and the output will be a ranking of the mathematical distributions which best captures the data. This tool is useful when historical data about a process is available. The OptQuest function allows for a simulation model to be optimized through the manipulation of variables and resources in a set of constraints. A user simply sets the model constraints and chooses the desired function to be optimized, and then several iterations are performed until an optimum value is achieved. However, for my thesis the input analyzer and OptQuest function were not used.

3.7 Translating the Process into the Arena Software

Converting the model logic flow and capturing the process behavior in a simulation model is the most critical step of creating a business process model. If you have one and not the other, then the model will not yield accurate results. Through the use of several types of model building blocks, Company DC's contract closeout process was modeled in the Arena software. The model began with the design of having 3 experienced resources (workers) and hiring two new resources (workers) to serve as resources in "Week 1 and 2 Tasks", "Rework", and "Compliance Rework" sub-processes. In order to test system behavior several different iterations of the model were created in order to simulate operating conditions with varying levels of experienced and new worker resources. This step in essence implements the system revision step of Forrester's method before any preliminary results are generated. The following levels of experienced and new workers were

simulated, and are summarized in Table 3.4. Staffing levels for all other resources, as summarized in Table 3.5, remain constant the same for different simulations. The Arena Logic Flow for each simulation is included in Appendix B.

3.7.1 Assumptions and Run Parameters

The design of Arena logic is important to model success, but the assumptions and simulation run parameters also help define model success. When contract closeouts would enter into the simulation the assumption that work was evenly distributed to workers was taken, and accomplished by using an N-way by chance Decision module. The N-way by chance Decision block allowed for a percentage of the closeouts to be directly assigned to a worker. For instance, if there were 4 workers, each would receive 25% of the contract closeouts which entered in the model. For the “Compliance Review” process the closeout packets were simply split in half (50%/50%) between the two Compliance workers.

Table 3. 4: Worker Resource Levels

Worker Resource Level	Total Number of Workers
3 experienced	3
3 experienced plus 1 new	4
4 experienced	4
3 experienced plus 2 new	5
4 experienced plus 1 new	5
5 experienced	5
4 experienced plus 2 new	6
6 experienced	6

Table 3.5: Resource Levels

Resource Name	Number of Resources
Project Leader	1
Compliance Worker	2
Legal	1
CFO	1

Another assumption that had to be captured was the learning curve for new workers. It was decided that after completing the “Week 1 and 2 Tasks” for 3 closeout packets, a new worker, who had longer processing times, would take on the processing time of the experienced workers. Through the use of a Decision and Hold module, this logic was able to be captured.

Since the model features three different types of contracts (DOD, non-DOD, and subcontracts), a different Create module was used for each type. The assumption that the prioritization of contracts beginning with Department of Defense as highest priority, then non-Department of Defense, and then finally subcontracts. This was accomplished by holding all non-DOD contracts at the beginning of the system until all DOD contracts were completed, and holding all subcontracts until the entirety of both DOD and non-DOD contracts were completed.

Simulation run parameters are used to specify how long and under what conditions a simulation is run. The contract closeout simulation models were different than most models in that there was no set replication length. The scope of the model sought to continually process contract closeouts until all were completed and submitted to DCAA. By setting the replication length in the *Run Setup* menu box in Arena the model would run until all entities, in this case contract closeouts, exited the model. Each model was replicated 100 times to normalize the

behavior of the system. For this process there was no warm-up period used since this process has a finite amount of entities and not continuous. Finally, the base time units used for data collection is in days because of the length of the process will be over a year.

3.7.2 Model Features

One of the key focuses of this model and simulation design was accurately capturing the work patterns of employees. A time pattern schedule was set up to define the availability of resources for the contract closeout process. It was assumed that all resources followed the same Monday through Friday work schedule, taking a 30-minute lunch break every day.

Monday through Thursday resources had a 9-hour work day, while Friday they worked a shorter 7 1/2 –hour work day, as typical in many office settings. Table 3.6 is the work week for each resource.

Dates defined as holiday, which will be described later, will supersede the standard weekly work schedule. In order for the models to successfully operate in the Arena software the schedule rule of Preempt had to be taken. Preempt assumption must be taken because of

Table 3.6: Weekly Work Schedule

Day of the Week	Start Working	Lunch Break		End Working
		Start	End	
Monday	8:00 AM	12:00 PM	12:30 PM	5:30 PM
Tuesday	8:00 AM	12:00 PM	12:30 PM	5:30 PM
Wednesday	8:00 AM	12:00 PM	12:30 PM	5:30 PM
Thursday	8:00 AM	12:00 PM	12:30 PM	5:30 PM
Friday	8:00 AM	12:00 PM	12:30 PM	4:00 PM

interruptions in the processing due to resource schedules. When a contract closeout packet enters one of the process modules and in mid-processing the schedule tells the resource that their day is over, the semi-processed closeout packet is held until the resource returns (in the morning or from the weekend/holiday) and finishes the processing.

One special feature I integrated into the scheduling was the occurrence of Federal and typical office holidays through New Year's Day 2013. For these dates all resources will be counted as unavailable. Since when the simulation is run it takes into account a start date (the current date as default), the model will only take into account specific holiday dates which will occur during the duration of the simulation. This totally eliminates having to make the assumption that resources will have a certain amount of days off during a process, and makes the model that much more accurate. A summary of the holidays integrated into the work schedule is listed in Table 3.7.

Arena has the option to run a warm-up period so that the simulation process will begin with entities in process, as supposed to an empty system. The warm-up period helps in simulating the congestion associated with a process. Oftentimes without a warm-up period an entity will process quicker than their true process times. The contract closeout process being simulated in this thesis a warm-up period will not be taken because it is not a continuous or repetitive process, thus certain resources will not be utilized at the process commencement. Also, the

Table 3.7: Summary of Schedule Holidays

Holiday	Year	Date(s)
Labor Day	2009	Monday September 7
Thanksgiving Holiday	2009	Thursday November 26 - Friday November 27
Winter Holiday	2009	Thursday December 24 -Friday December 25
New Year's Holiday	2009/2010	Wednesday December 30 - Friday January 1
Martin Luther King Day	2010	Monday January 18
Memorial Day	2010	Monday May 31
Independence Day	2010	Sunday July 4
Labor Day	2010	Monday September 6
Thanksgiving Holiday	2010	Thursday November 25 - Friday November 26
Winter Holiday	2010	Friday December 24 - Saturday December 25
New Year's Holiday	2010/2011	Thursday December 30 - Saturday January 1
Martin Luther King Day	2011	Monday January 17
Memorial Day	2011	Monday May 30
Independence Day	2011	Monday July 4
Labor Day	2011	Monday September 5
Thanksgiving Holiday	2011	Thursday November 24 - Friday November 25
Winter Holiday	2011	Saturday December 24 - Sunday December 25
New Year's Holiday	2011/2012	Friday December 30 - Sunday January 1
Martin Luther King Day	2012	Monday January 16
Memorial Day	2012	Monday May 28
Independence Day	2012	Wednesday July 4
Labor Day	2012	Monday September 3
Thanksgiving Holiday	2012	Thursday November 22 - Friday November 23
Winter Holiday	2012	Monday December 24 - Tuesday December 25
New Year's Holiday	2012/2013	Sunday December 30 - Tuesday January 1

resources not utilized at the beginning of the process will be heavily burdened at the end of the process.

In order to record this value a combination of a Decision module and a Record module was setup so that all entities would pass through the Decision module as a counter, and the last closeout packet, which was valued at 642, was sent to the Record module and the current time was recorded. This was similarly done in order to capture when all DOD and non-DOD contracts exited the process in order to capture the time of their completion. Except for the Decision modules was based off it the value equaling 242 and 442, the last DOD and non-DOD closeout packets to exit the system. It can be assumed that the time when all contract closeouts are completed is the same time as when subcontracts are completed, due to the prioritization scheme.

Chapter IV

Results

The simulation models were run in the Arena software under each different level of worker resources, and an output file for model was generated in Microsoft Excel. These Microsoft Excel output worksheets contained statistics about the resources and processes involved in the simulation. All models below are summarized from the Arena Output from the software and from the generated Microsoft Excel files.

In Table 4.1 the minimum, average, and maximum amount of time it took for the process to complete under the different levels. By observing the values on the table it is apparent that by increasing the Worker resource amount the entire process length is significantly reduced. Using the average completion time lengths, it takes 3 experienced workers nearly 2 ½ years longer to complete the process than 6 experienced workers. This is a powerful number when presented to upper-level management whom is hesitant to bring on more resources for a project.

It is important to notice that some iterations have the same number of resources as other iterations, just in different combinations of experienced and new resources. The worker resource level of “3 experienced plus 1 new level” does have slightly lower minimum, average, and maximum process time lengths than “4 experienced” which is not the expected result

Table 4.1: Summary of Times to Complete Contract Closeout Process

Worker Resource Level	Total Number of Workers	Time (days)		
		Minimum	Average	Maximum
3 experienced	3	1931	2079	2311
3 experienced plus 1 new	4	1546	1649	1805
4 experienced	4	1520	1654	1808
3 experienced plus 2 new	5	1252	1383	1541
4 experienced plus 1 new	5	1287	1373	1512
5 experienced	5	1268	1369	1507
4 experienced plus 2 new	6	1133	1241	1468
6 experienced	6	1072	1173	1323

when having the same amount of resources, but can be explained by internal sub-process variation. Since it only takes 3 contracts for a new worker to become experienced this is only a tiny percentage (0.0046%) of the 642 total numbers of contracts. When comparing the pairs of “3 experienced plus 2 new” to “4 experienced plus 1 new” and “4 experienced plus 2 new” to “6 experienced”, the iterations with less or no new resources have the expected slightly shorter process length, since the learning curve for new workers is designed to increase processing times for only a short period of time. The expected trend of increased workers increases productivity and operational time of the closeout process was achieved when comparing various levels of worker resources.

The ranges of the amount of time to complete the contract closeout process can be better visualized through use of box plots. Box plots capture the descriptive statistics of the sample minimum, lower quartile (Q1), median (Q2), upper quartile (Q3), and the sample maximum.

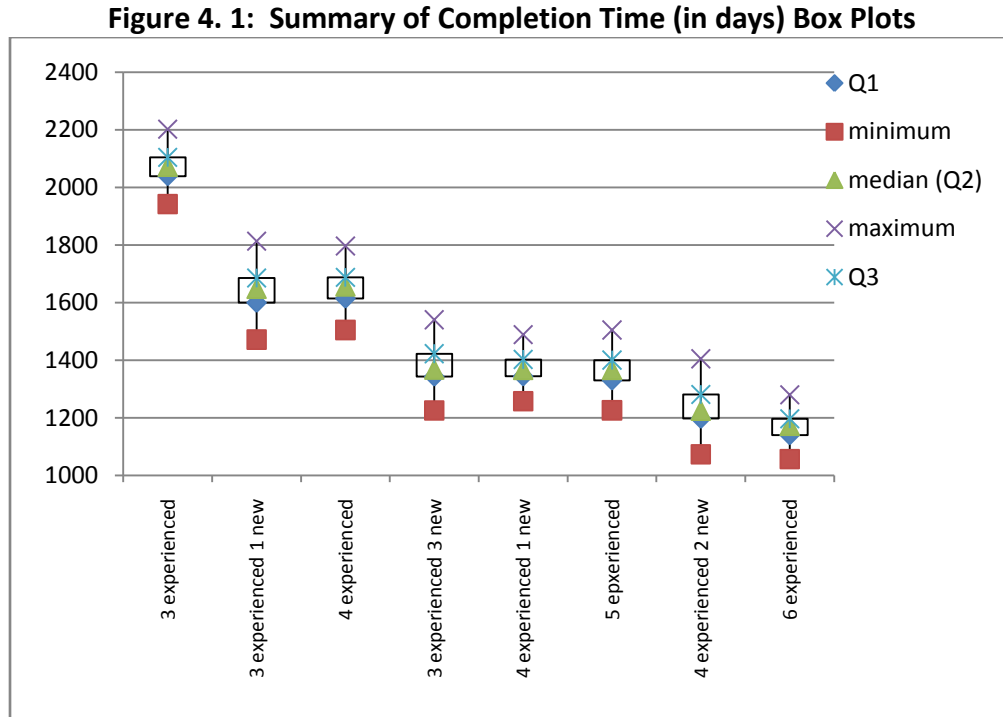


Figure 4.1 is a summary of the box plots at all Worker Resource Levels, and Figures 4.2 – 4.5 summarize the Worker Resource Levels at the totals of 3, 4, 5, and 6 respectively. The y-axis of Figures 4.1 – 4.5 is associated with units in days. Comparing box plots at different Worker resource totals clearly and effectively captures the time reduction of the process by adding one or more resources. There is a reduction in completion time variation as the amount of new workers associated with a process is reduced, with the exception of the “4 experienced 1 new” model. Reduction of process variation is an important characteristic of a process to consider when modeling. Lower variation allows a higher amount of precision in determining probable results. Some outliers did occur (not included on the box plots), but were only deviated from the range slightly with the exception of one value of “3 experienced” model which could be

Figure 4. 2: Box Plot at a 3 Worker Resource Level

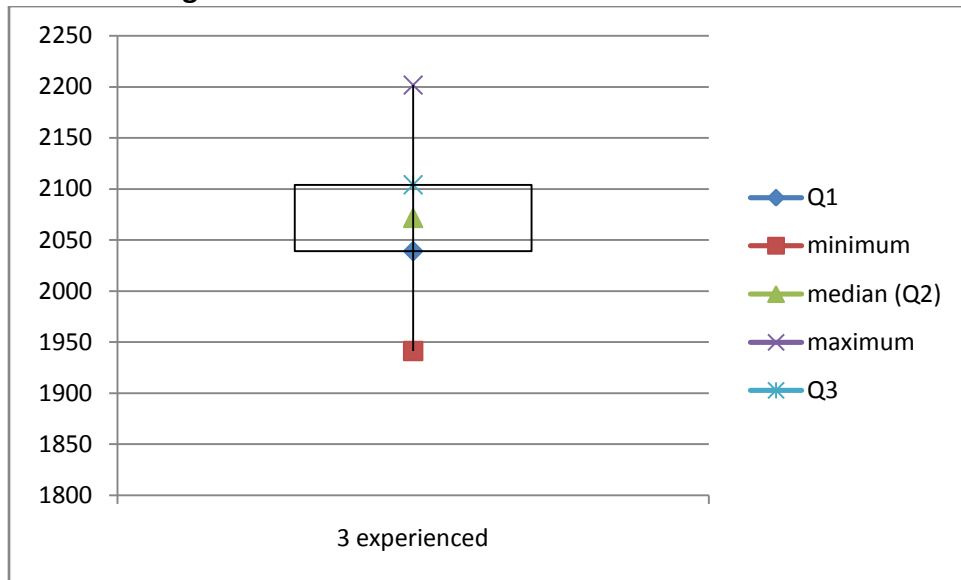


Figure 4. 3: Box Plots at a 4 Worker Resource Level

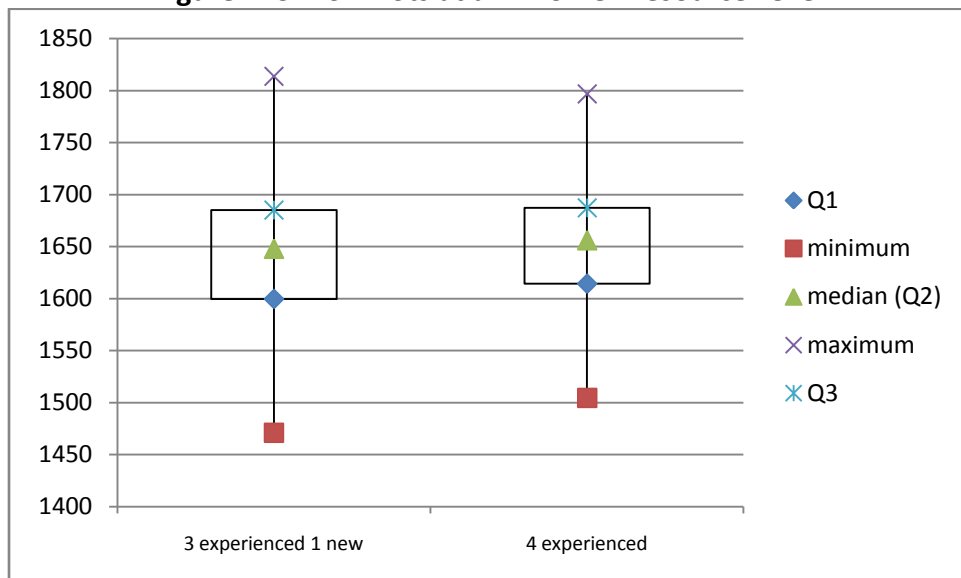


Figure 4. 4: Box Plots at a 5 Worker Resource Level

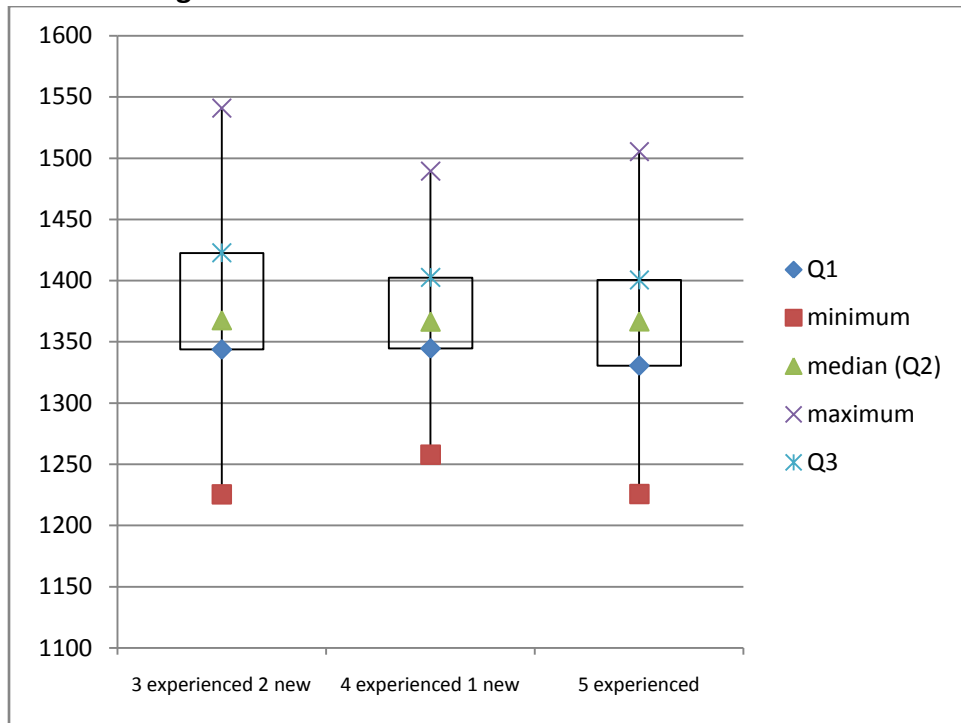
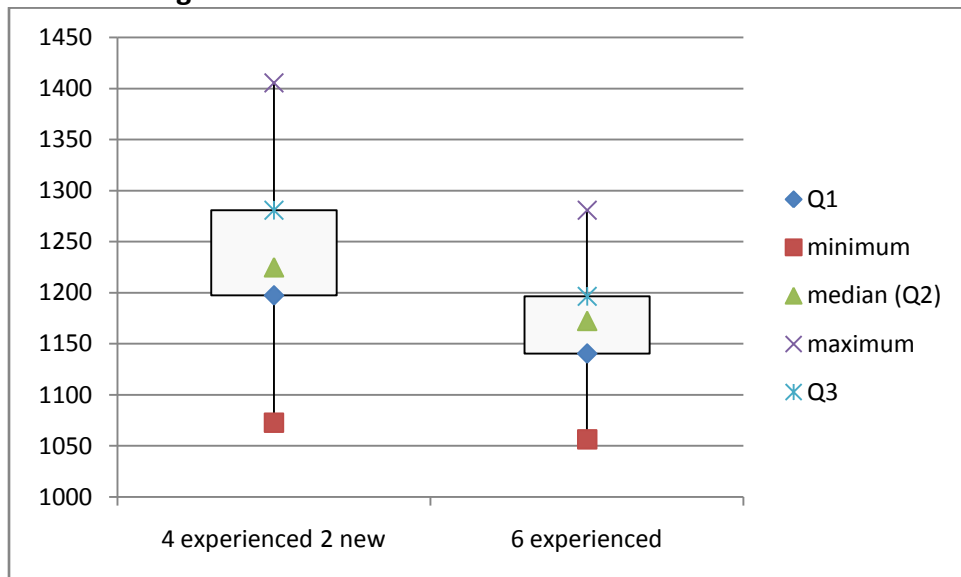


Figure 4. 5: Box Plots at a 6 Worker Resource Level



accounted for by variation. The method used to construct the box plots was from Montgomery and Runger (2007).

Assuming that at each level of resources it will take the average amount of time, given in days above, to complete the entire process, then the amount of years, months, and days can be calculated. First take the time in days and divide it by 365 (days). The resulting portion of that number left of the decimal is the amount of years. Then take the decimal remainder and multiply it by 12 (months). This resulting portion left of the decimal is the amount of months. Finally multiply the decimal remainder by 30 (days), and round this up to the next integer. The resulting values, located in Table 4.2, can then be used to determine an expected process end date given a starting date. This can be done because a standardized work schedule and holidays were integrated into the simulation model, so there is only considered to be a small amount variance between the projected end date and the actual end date. For instance, if the

Table 4.2: Summary of Time Length Horizons

Worker Resource Level	Total Number of Workers	Average Time Horizon		
		Years	Months	Days
3 experienced	3	5	8	11
3 experienced plus 1 new	4	4	6	7
4 experienced	4	4	6	12
3 experienced plus 2 new	5	3	9	15
4 experienced plus 1 new	5	3	9	5
5 experienced	5	3	9	1
4 experienced plus 2 new	6	3	4	24
6 experienced	6	3	2	17

project begins July 13th, 2009 and 6 experienced workers are used, then the expected project end date is estimated to be October 30th, 2012.

An area of particular interest is the scheduled utilization of all the resources in each different iteration, which reflects some of the dynamics of the closeout process with respect to the resources. The scheduled utilization is of particular interest because this measure focuses on the utilization of a particular resource during scheduled periods of work, and is captured in Equation (1). Since the models created heavily revolve around schedules the true effect of the resource on the system can be captured. In examining the scheduled utilization of many resources it is important to recognize that not all resources are solely dedicated to this process. The work of the CFO, Compliance Workers, and Legal Department in the contract closeout process only plays a small role in their overall responsibilities to the company and their organizations. On the other hand all Workers and the Project Leader are solely dedicated to the contract closeout process, so their utilization should be maximized to this process.

$$\text{Scheduled Utilization} = \frac{\text{Amount of Time Utilized}}{\text{Amount of Time Scheduled}} \quad (1)$$

The data used for the scheduled utilization rates were averaged over the 100 replications to gain a better stabilize resource behavior. Tables 4.3 – 4.10 are the average resource scheduled utilization for all 8 iterations. When comparing the scheduled utilization rates between different iterations it is important to observe the number of Worker resources. Comparing

iterations with the same Worker resource levels seem to produce almost identical results for all resources except for workers. Though the variance in scheduled utilization between Worker resources is slightly higher than all other resources, in same Worker level iterations, it is still systematically low.

Table 4.3: “3 Experienced” (3 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.088
Compliance Worker 1	0.069
Compliance Worker 2	0.069
Legal	0.056
Project Leader	0.277
Worker 1	0.929
Worker 2	0.897
Worker 3	0.900

Table 4.4: “3 Experienced Plus 1 New” (4 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.114
Compliance Worker 1	0.088
Compliance Worker 2	0.089
Legal	0.072
Project Leader	0.355
Worker 1	0.885
Worker 2	0.867
Worker 3	0.870
Worker 4 (New)	0.879

Table 4.5: “4 Experienced” (4 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.113
Compliance Worker 1	0.089
Compliance Worker 2	0.089
Legal	0.072
Project Leader	0.355
Worker 1	0.875
Worker 2	0.873
Worker 3	0.876
Worker 4	0.874

Table 4.6: “3 Experienced Plus 2 New” (5 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.137
Compliance Worker 1	0.106
Compliance Worker 2	0.107
Legal	0.086
Project Leader	0.427
Worker 1	0.853
Worker 2	0.829
Worker 3	0.835
Worker 4 (New)	0.889
Worker 5 (New)	0.815

Table 4.7: “4 Experienced Plus 1 New” (5 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.137
Compliance Worker 1	0.107
Compliance Worker 2	0.107
Legal	0.086
Project Leader	0.429
Worker 1	0.854
Worker 2	0.841
Worker 3	0.849
Worker 4	0.829
Worker 5 (New)	0.855

Table 4.8: “5 Experienced” (5 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.137
Compliance Worker 1	0.107
Compliance Worker 2	0.107
Legal	0.087
Project Leader	0.430
Worker 1	0.847
Worker 2	0.848
Worker 3	0.841
Worker 4	0.850
Worker 5	0.850

Table 4.9: “4 Experienced Plus 2 New” (6 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.152
Compliance Worker 1	0.118
Compliance Worker 2	0.119
Legal	0.096
Project Leader	0.475
Worker 1	0.754
Worker 2	0.753
Worker 3	0.748
Worker 4	0.742
Worker 5 (New)	0.855
Worker 6 (New)	0.833

Table 4.10: “6 Experienced” (6 Workers) Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.160
Compliance Worker 1	0.125
Compliance Worker 2	0.125
Legal	0.101
Project Leader	0.501
Worker 1	0.824
Worker 2	0.824
Worker 3	0.820
Worker 4	0.823
Worker 5	0.820
Worker 6	0.827

The only instance where there is significant scheduled utilization variance between same Worker resource levels is on Tables 4.9 and 4.10. Here scheduled utilization rates for nearly all resources for the “6 Experienced” model vary from the “4 Experienced Plus 2 New” model. Reasons for the increased variance level could be due to having two New Worker resources in the “4 Experienced Plus 2 New” model as opposed to no New Workers in the other model. This variance between these two models can be visualized in Table 4.1 when comparing the process completion times. In all instances (minimum, average, and maximum) there is a significant jump in days, ranging from about 40 to 70, in the “6 Experienced” completing before the “4 Experienced Plus 2 New” model. This could be a strong indication that the hiring of new, inexperienced outside resource onto a project, as opposed to moving experienced internal resource onto a project, might have a strong rendering on the process completion time.

In comparing the various levels of Worker resources it is important to notice that scheduled utilization rates of all resources, except Worker resources, increase as the level of Workers increase. The reason for this increase in utilization is that when the amount of Worker resources is increased the contracts closeouts move through the process quicker and reach the other resources more quickly. Logically thinking through the process, the faster a closeout packet reaches a process the more quickly it will be processed completely and exit the system. When all closeout packets are processed more quickly the time length of the process is reduced, thus reducing the amount of time resources are scheduled.

Table 4.11 is a summary of the average amount of time it takes for a particular type of contract to complete in the contract closeout process. Under the various iterations with the same Worker resource levels it is observed that the models without New Workers, which had learning curves, were slightly slower to finish the DOD and Non-DOD contracts, but narrowed the difference as the process continued. As previously discussed, the “3 Experienced Plus 1 New” model on average finishes 5 days before the “4 Experienced” model, but you can see that the “4 Experienced” model does finish the DOD contracts first. For all the combinations where 5 Workers were present there is a good reflection of how the learning curve slightly delays the completion of the entire process. The average completion time for the “4 Experienced Plus 1 New” model finishes slightly faster than the “3 Experienced Plus 2 New” model. In turn, the “5 Experienced” model on average completed each type of contract slightly quicker than the “4 Experienced Plus 1 New” model.

Table 4.11: Average Length to Complete Different Contract Types

Worker Resource Level	Total Number of Workers	Average Length to Complete (Days)		
		Type of Contract		
		DOD	Non-DOD	Subcontract
3 experienced	3	789	1445	2079
3 experienced plus 1 new	4	627	1142	1649
4 experienced	4	619	1144	1654
3 experienced plus 2 new	5	523	955	1383
4 experienced plus 1 new	5	520	948	1373
5 experienced	5	509	941	1369
4 experienced plus 2 new	6	502	872	1241
6 experienced	6	439	809	1173

The only models again with significant differences between completion dates are the models with 6 Worker resources. The model with “6 Experienced” model finishes 71 days (DOD), 71 days (non-DOD), and 76 days (Subcontracts) earlier than the “4 Experienced Plus 2 New” model with respect to the 3 types of contracts. Some of the variation can be attributed to variation within the sub-processes, but there must be variation related to bringing on New Worker resources. When the total number of New and Experienced Workers resources reaches a certain level, there appears to be significant jump in performance.

Queue lengths were examined in depth in my study because the undoubtedly bottleneck of the contract closeout system were the processes where Worker resources were utilized. The largest bottleneck in particular was at the beginning process at the “Week 1 and 2 Tasks” sub-process where files had to wait. Also, since Non-DOD closeouts were held until all DOD contract closeouts were completed, and all Subcontracts were held until all Non-DOD closeouts

were done they accumulated a lot of non-value-added time in queue. This is also the justification for different levels and combinations of Worker resources used in the study. The summary data for each model run is a file titled *Summary Arena Data.xlsx*, and the data for each model is included on a separate worksheet within the file.

Chapter V

Conclusions

5.1 General Conclusions

The practice of business process modeling is not a new concept, but in more recent years the application has expanded and models themselves has become increasingly robust. The application in BPM in this thesis proves there is a strong need for modeling and simulation, not just for planning for and monitoring a process, but for visualization of a process. If a process is poorly or yet to be defined, it is improbable that an optimum process will be initially developed.

My application defined the contract closeout process, developed a model reflecting the process flow, and created a simulation mimicking the process behavior. This simulation model allows for staff planning for the process, and also permits the user to implement any adjustments to various components the process to react to real world changes. The learning curve aspect of the model helps to compensate for true bureaucratic delays, such as hiring, which occur in almost every organization. The simulation models could also be paired with true cost data to determine whether moving an internal employee to the project, hiring a new employee, or leaving staff level the same is the most cost effective decision. By integrating a realistic work week schedule and holidays the model also allows for more realistic planning and measurement of the system. Though vacations or sick leave is not taken into account in this model it would be easy to compensate for this missed productivity using the same technique used to integrate

holidays. The model could also be used to determine how if an employee took a vacation during a specific period it would affect the throughput and performance of the system.

A model and simulation, such as this contracts closeout model, can be used to appease the customer, in this case the government. If a customer sees the high level of effort an organization is putting into the completion of a task, they tend to be more satisfied with the performance of the organization.

5.2 Contribution of the Thesis

In this thesis the area of business process modeling was both explored and expanded. This application:

- Explored the field of contracts management, in which business process modeling had not previously been applied.
- Created a descriptive planning tool for the contracts closeout process. This tool allows an organization to visualize and simulate their process, and gain better control over their operations.
- Allowed for the development of a strategic model for integrating change into the contract closeout process. By identifying the critical flow of a process, a restructuring of the process can be made to better productivity and flow.
- Evaluated queuing theory principles in the contract closeout process.

The remainder of the thesis will present a more strategic approach to the contract closeout process to better process closeout packets.

5.3 Strategic Changes and Future Research

To better process contract closeout packets Company DC might want to restructure and rethink the flow and some of the steps in the contract closeout process. Assumptions about the process and organization must be taken, and certain processes/steps cannot be eliminated.

The assumptions for an improved strategic model are:

- There is an adequate work pool of qualified workers.
- Radical restructuring of the process can occur without holdups from upper management.
- Organizational boundaries can be crossed.
- Reworks may be completed by the resource which reviews a contract closeout packet.
- Government regulations and control could be ignored.

From studying the flow of Company DC's contract closeout process in Figure 3.1 it is obvious that a great deal of delay is incurred during all of the reworks. The reworks draw the resources away from the initial processing of closeout packets. The assumption that reworks can be done by a reviewer is important to improvement of the process flow. One major change that would be implemented would be the replacement of the Worker resources with resources as trained and qualified as the Project Leader. If highly trained and qualified individuals completed virtually all the packet processing of the closeout packets at the beginning of the process this

would reduce the amount of reworks and processing done by other resources. In Figure 5.1 is a rendering of the more strategic approach to the contract closeout process might appear. Though it is easy to say these changes are logical and would significantly improve process output and flow, the steps to institute all changes would be impossible, since this process is closely monitored by the Federal government.

In order to demonstrate the potential improvement which could result from process restructuring, two iterations of the proposed logic flow in Figure 5.1 were simulated in Arena. For these new processes, all resource levels stayed the same except instead of regular Workers at the beginning of the process; Experts were inserted in their processes, which generated all necessary closeout packet documentation. The process times were also altered for the Week 1 and 2 Tasks were decreased since Experts are assumed to work more efficiently, while Compliance Review and CFO Review to reflect increased processing due to the integration of rework. The descriptive values of the processes are included in Table 5.1.

Proposed Contract Closeout Process

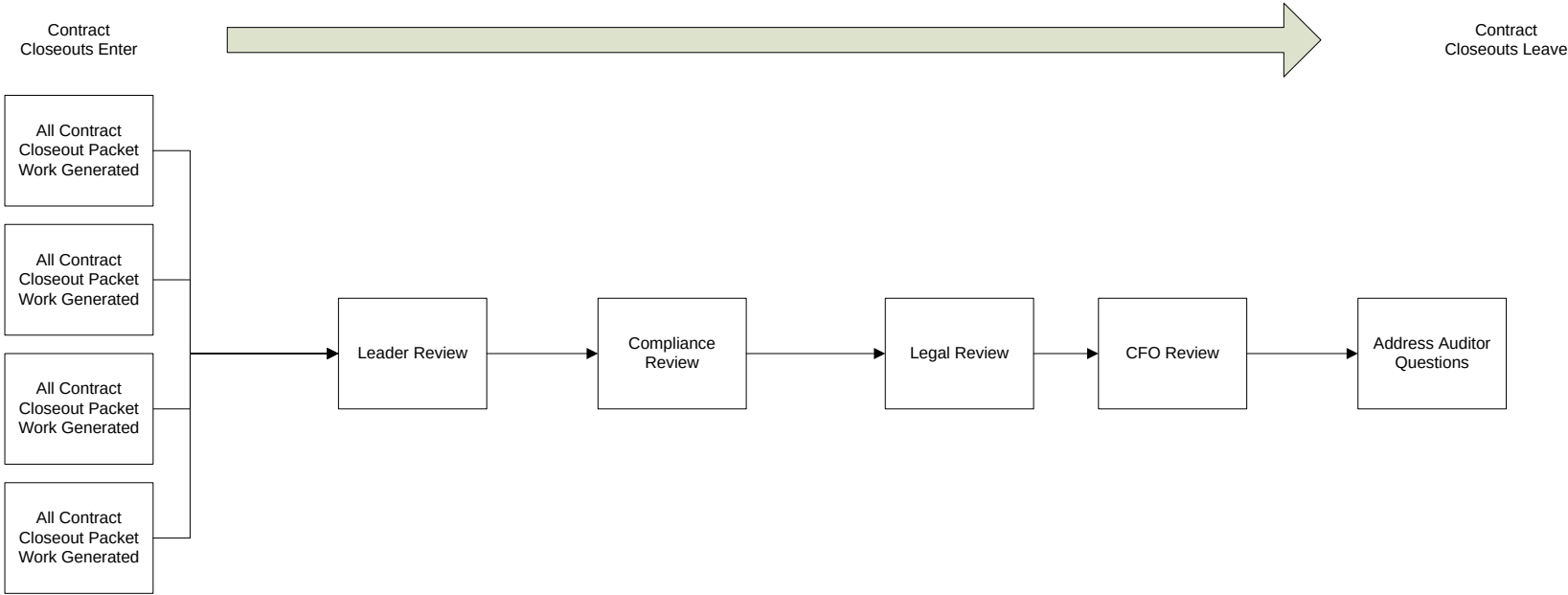


Figure 5. 1: Strategically Improved Contract Closeout Process Flow

Table 5.1: Revised Process Time Descriptions

Process	Mathematical Distribution	Minimum	Mean	Maximum	Units	# of Resources
Week 1 and 2 Tasks	Triangular	31.5	40.5	49.5	Hours	Experts
Project Leader Review	Constant	N/A	4	N/A	Hours	Project Leader
Compliance Review	Uniform	3	N/A	4.5	Hours	Compliance Workers
Legal Review	Constant	N/A	1	N/A	Hours	Legal
CFO Review	Triangular	1	2	3.5	Hours	CFO
Address Auditor Questions	Triangular	0.5	1.5	2.5	Hours	Project Leader

Tables 5.2, 5.3 and 5.4 shows a significant reduction in the amount of time to fully complete the contract closeout process when compared to Tables 4.1, 4.2, and 4.11. Though it would logical to make the attempts to reduce the amount of total time, this model does make bold assumptions, which are not likely feasible to most organizations.

Table 5.2: Revised Process Completion Time to Completion

Worker Resource Level	Total Number of Expert Workers	Time (days)		
		Minimum	Average	Maximum
Revised Process 4	4	1152	1250	1380
Revised Process 5	5	904	1024	1124

Table 5.3: Revised Process Completion Time Horizon

Worker Resource Level	Total Number of Workers	Average Time Horizon		
		Years	Months	Days
Revised Process 4	4	3	5	3
Revised Process 5	5	2	9	20

Table 5.4: Revised Process Completion by Contract Type

Worker Resource Level	Total Number of Expert Workers	Average Length to Complete (days)		
		Type of Contract		
		DOD	non-DOD	Subcontract
Revised Process 4	4	460	859	1250
Revised Process 5	5	381	705	1024

Tables 5.5 and 5.6 do show increased utilization among resources other than the Expert Workers, which is encouraging from a process improvement standpoint. Possibly integrating a mix of Workers and Expert Workers could yield a more efficient process, which might be more realistic when taking a survey of the potential labor pool.

Future research could look into susceptibility of the government to change its policies and procedures to make processes more efficient to organizations that must closely abide by these government regulations. Studying in-depth the co-dependencies that occur between the government and a contractor, and developing improvement strategies. The contracts management area is one area that these co-dependencies occur often and create caustic barriers.

Table 5.5: “Revised Process 4” Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.186
Compliance Worker 1	0.162
Compliance Worker 2	0.161
Legal	0.086
Project Leader	0.473
Expert Worker 1	0.876
Expert Worker 2	0.869
Expert Worker 3	0.865
Expert Worker 4	0.873

Table 5.6: “Revised Process 5” Utilization Rates

Resource	Average Scheduled Utilization Rate
CFO	0.165
Compliance Worker 1	0.143
Compliance Worker 2	0.144
Legal	0.104
Project Leader	0.574
Expert Worker 1	0.851
Expert Worker 2	0.848
Expert Worker 3	0.839
Expert Worker 4	0.838
Expert Worker 5	0.851

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APPENDICES

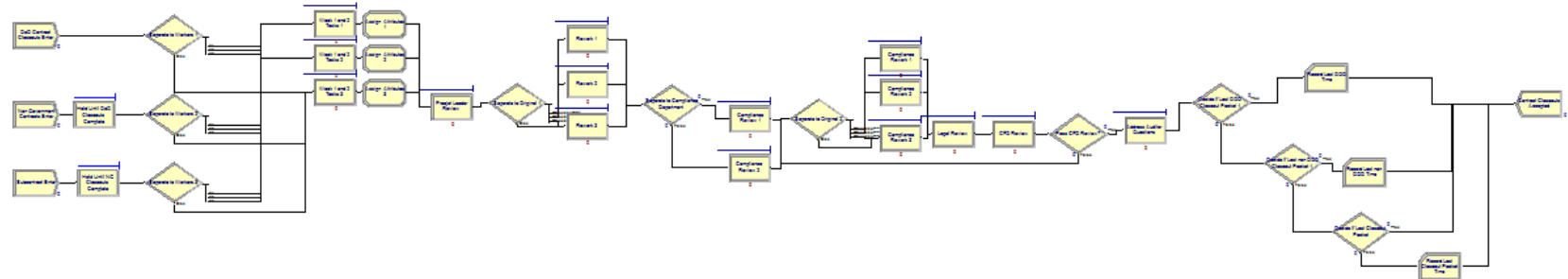
Appendix A: Contract Closeout Process Questionnaire

Data Collection

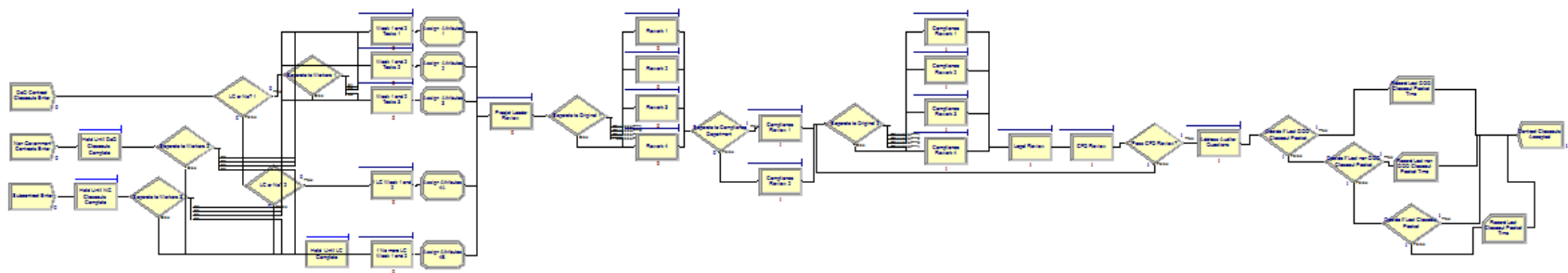
1. How long does it take to do week 1 activities (shortest, average, long)? Error/Failure rate?
 - a. Number of workers?
2. How long does it take to do week 2 activities (shortest, average, long)? Error/Failure rate?
3. Learning curve times for both week 1 and 2 activities?
4. How many completed before learning curve is done?
5. What types of issues are holding up week 1 and 2 activities?
 - a. Contracts? Modifications? Subcontractors? Delivery Orders?
6. How long does compliance review take (shortest, average, long)?
7. How many pass compliance review (percentage)?
8. How long does legal review take (shortest, average, long)?
9. How many pass legal review (percentage)?
10. How long does CFO review take?
11. How many pass CFO review (if available)?
12. Types of questions which arise from auditors? How long do they take to address?
13. Worker schedules?
14. Are weekly meetings affecting output of contracts?
15. How many Department of Defense (DoD) contracts are there?

16. How many non-Department of Defense contracts are there?
17. Utilizing prioritization?
18. How are subcontracts fitting into the picture?
19. How many subcontracts are there?
20. Accounts Payable/Billing activities interfering?
21. How many have been submitted? Accepted? Cost savings? Contract costs?
22. Cost to hire new worker?
23. How many contracts expected for 2003? 2004? After?
24. Is (L:) drive (network drive) being populated with information?
25. What performance measures do you want to be focused on?
 - a. Utilization?
 - b. Throughput?
 - c. Time in Queue/Process?
 - d. Average Processing Time?
 - e. Times Processed?
 - f. Validity of Model?
 - g. Flexibility of Model?

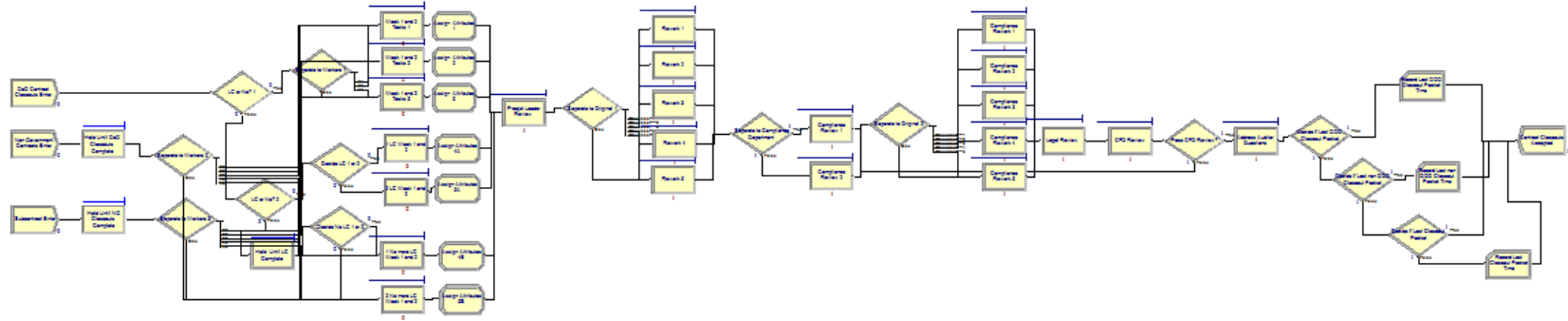
Appendix B: Models built in Rockwell Arena software



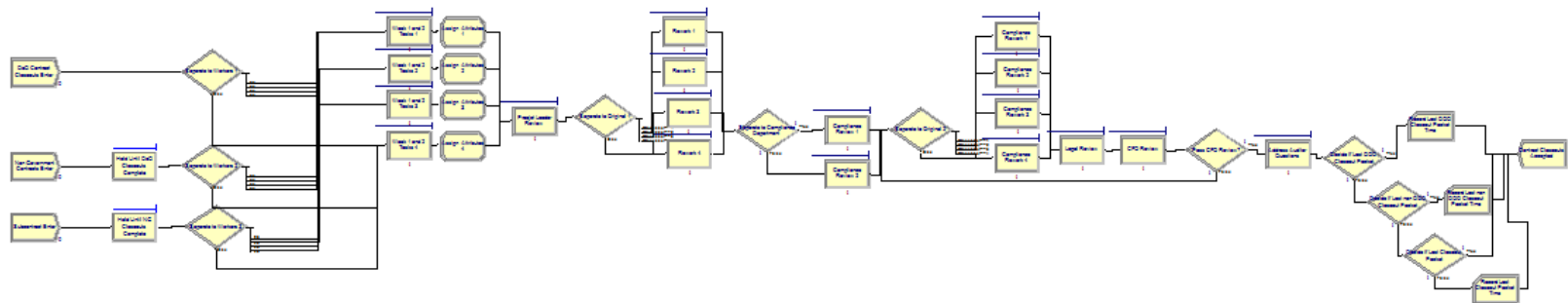
3 Experienced Workers



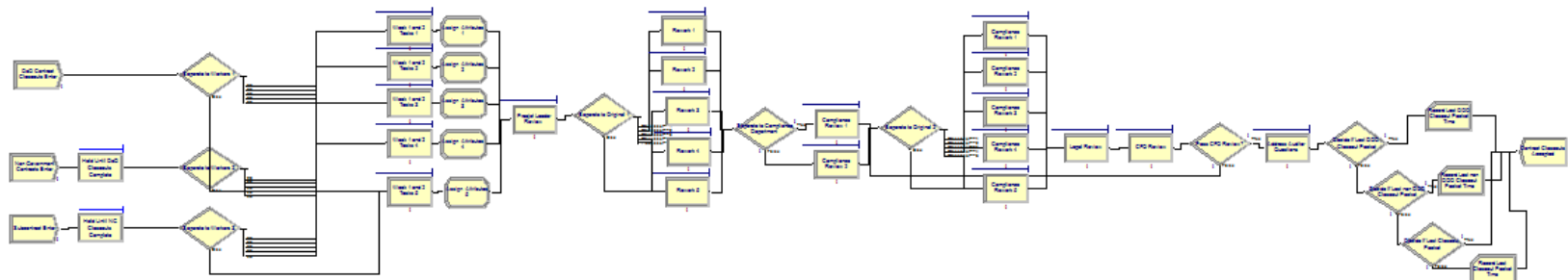
3 Experienced Workers Plus 1 New Worker



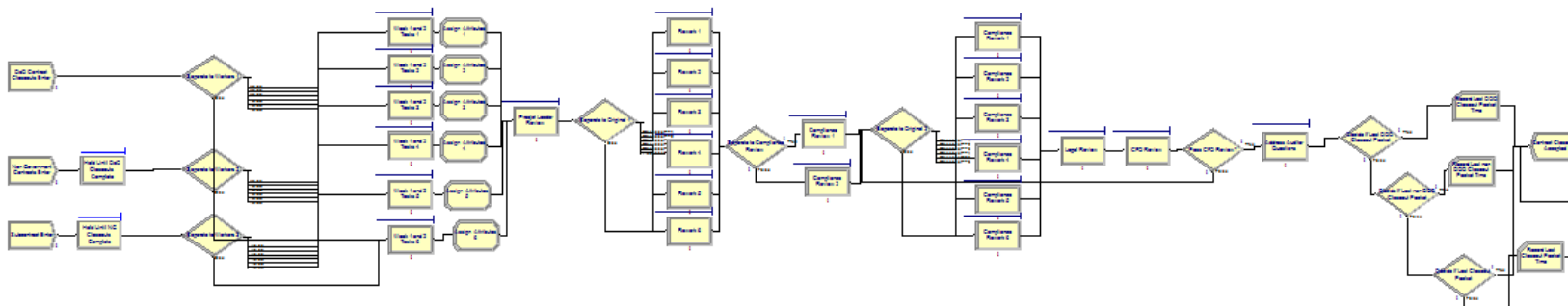
3 Experienced Workers Plus 2 New Workers



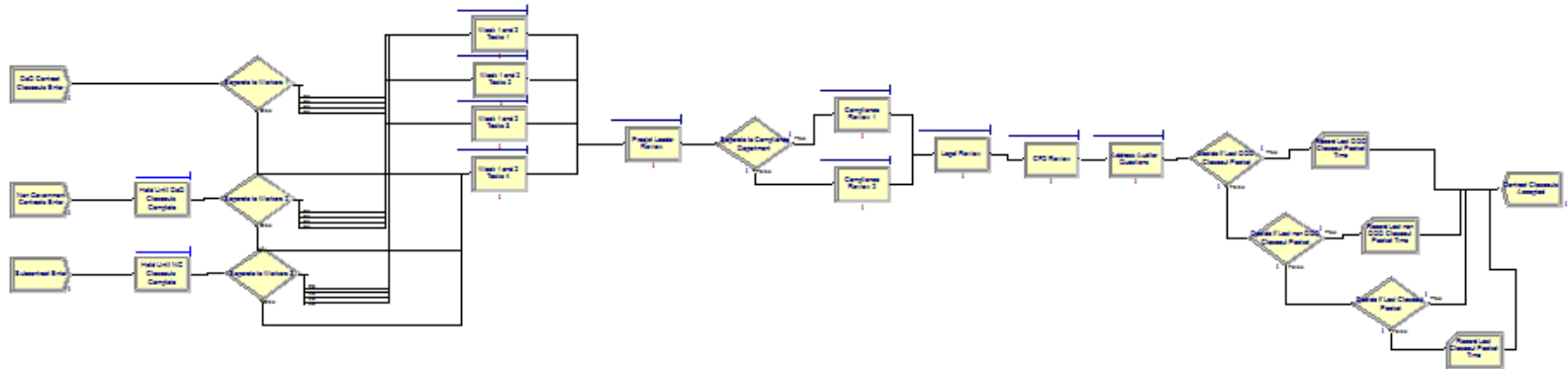
4 Experienced Workers



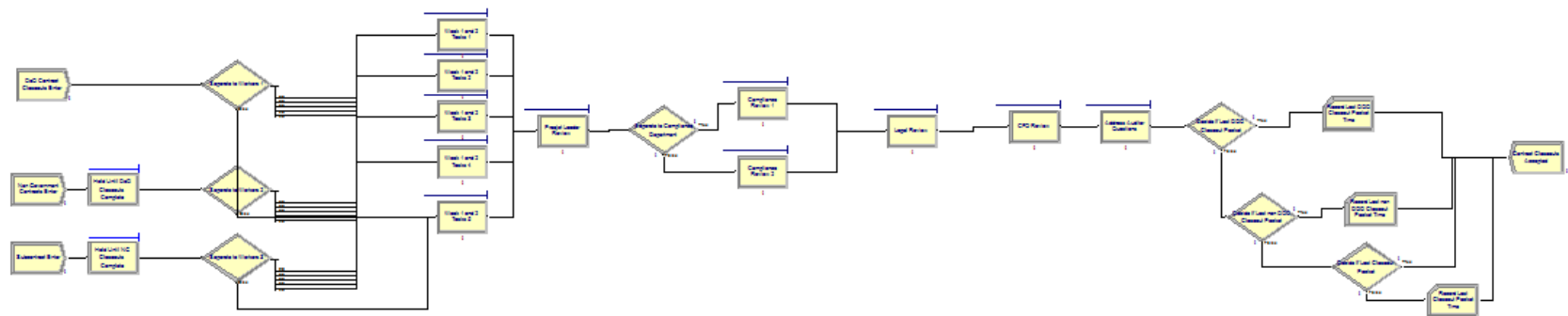
5 Experienced Workers



6 Experienced Workers



Revised Process 4



Revised Process 5

VITA

Clayton Jerrett Capizzi was born on Saturday, November 23, 1985 at Fort Belvoir, Virginia. He attended West Springfield High School in Springfield, Virginia. For his undergraduate degree Clayton attended James Madison University in Harrisonburg, Virginia earning a Bachelor of Science in Integrated Science and Technology (ISAT) with a concentration in Engineering and Manufacturing in the spring of 2008. Clayton next attended The University of Tennessee, Knoxville beginning in the fall of 2008 working towards a Master of Science in Industrial Engineering. He worked under the direction of Dr. Joseph Wilck as a Graduate Research Assistant, and is a member of the both the Society of Manufacturing Engineers (SME) and the Institute of Industrial Engineers (IIE). Clayton plans on moving back to the Washington D.C. area in pursuit of a career utilizing his skills in Industrial Engineering.