A Framework For Workforce Management An Agent Based Simulation Approach

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A FRAMEWORK FOR WORKFORCE MANAGEMENT AN AGENT BASED SIMULATION APPROACH

by

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ABSTRACT

In today's advanced technology world, enterprises are in a constant state of competition. As the intensity of competition increases the need to continuously improve organizational performance has never been greater. Managers at all levels must be on a constant quest for finding ways to maximize their enterprises' strategic resources. Enterprises can develop sustained competitiveness only if their activities create value in unique ways. There should be an emphasis to transfer this competitiveness to the resources it has on hand and the resources it can develop to be used in this environment. The significance of human capital is even greater now, as the intangible value and the tacit knowledge of enterprises' resources should be strategically managed to achieve a greater level of continuous organizational success. This research effort seeks to provide managers with means for accurate decision making for their workforce management. A framework for modeling and managing human capital to achieve effective workforce planning strategies is built to assist enterprise in their long term strategic organizational goals.

Dedicado en especial a:
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LIST OF ACRONYMS

ABS	Agent Based Simulation
DES	Discrete Event Simulation
FTP	Fulltime Personnel
HQ	Headquarters
KSC	Kennedy Space Center
MRM	Multi-Resolution Modeling
NASA	National Aeronautics and Space Administration
OMB	Office of Management and Budget
OTFTP	Other Than Fulltime Permanent
SD	System Dynamics

CHAPTER 1. INTRODUCTION

1.1. Introduction

In today's business enterprises, workforce managers are influenced by many factors, including the drive for effective methodologies and processes to improve performance. In addition, a workforce's perceptions and feelings about the work environment is affected by cost of living, scarce technical human capital, global economy, and unemployment rate among others. To manage human capital in a manner consistent with enterprise or business program success, and to strategically position an enterprise to execute its goals, it is necessary to understand how all of these different influencing factors work together to produce an optimal overall workforce climate.

Workforce management is an enterprise's most crucial human capital and managerial concern. It is the basis of strategic goal accomplishment. Workforce management is a process that encompasses the identification and organization of the number and mix of human capital. This human capital is paired in accordance to the skills requested and required by the different business programs in order to accomplish the enterprise's long term goals and objectives. Sound workforce management strategies begin with a well-developed and executed strategy, a reliable and structured data repository, a thorough internal and external work environment examination, and a fierce recognition of the normal tendencies (Cotten, 2007). In order to accomplish a successful analysis of the workforce, the plan should be based on a continuous improvement process. It is accomplished, according to Keel, (2006), following four successive steps and keeping in mind that there is always room for more improvement in any process. These steps are: (1) defining the enterprises' objectives and key goals; (2) conducting sound human capital analysis and evaluation; (3) implementing the resulting workforce plan; and (4) monitoring, evaluating and revising the strategies.

In general, the whole process of workforce planning can be further categorized into four key stages: (1) Demand analysis; (2) Supply analysis; (3) Gap analysis; and (4) Strategy development and deployment (Keel, 2006). Forecasting an enterprises' workforce, which constitutes an integral part of demand and supply analysis phases of workforce management, is the goal of this research effort. Therefore, the methodology being proposed identifies the essential relationships that exist among workforce factors. The main components that form the bases of this research are: (1) collecting organizational quantifiable parameters from human capital and program requirements data; (2) determining organizational dynamics parameter data from workgroup interaction and brainstorming sessions; (3) capturing human capital interactions, cause-and-effect relationships among the available workforce have to be taking into account to model and analyze performance; and (4) A software system, based on human components characteristics and program requirements that will help predict future workforce needs and trends.

1.2. Problem Statement

The environment of technical enterprises of today seeks to increase the integration of systems through a growing interest in simulation approaches in order to manage their enterprise. Enterprise managers are under constant and increasing pressure to go beyond traditional barriers and manage their systems in more synchronized ways. Thus far, managers lack a decision-making framework to comprehensively model and analyze their system's management policies and performance. This decision-making framework needs to be easy to use, comprising, expandable, and provide ways to model details changes and availability of data, in order to facilitate varying levels of analyses that are adequate for different enterprise levels. For instance, a decision-making support system designed to accommodate workforce planning needs to include: decision making strategic and tactical levels. Realizing the fact that technical enterprises engage in project and non-project activities, suggests various decision making periods and planning perspectives and different needs for information in resulting analyses and evaluations are required. Furthermore, interactions and cause-and-effect relationships among all management levels and engineering departments have to be considered in the model design and evaluation of system performance (Marin et al., 2006).

1.3. Research Question

Enterprise organizational changes emphasize on "doing more with less" and bring about changes, additions and deletions to existing and new business programs. The high technological changes, program uncertainties and many complex and conflictive forces have driven the development of effective workforce planning strategies to become a very difficult challenge. Previous work has shown that the development of planning models, organizational learning, and experimentation will nurture this ability. Traditional methods for workforce management no longer capture all interactions and characteristics of human capital and its environment, just allocating resources can no longer be the norm in the ever changing technological world. Thus promoting organizational planning in order to achieve effective workforce planning strategies to accomplish the required goal for program success becomes the norm. Therefore when arriving at a consensus on why, what, and how of workforce systems dynamic nature can influence the analysis of management policies and performance of enterprise systems develops into a new research area. This research effort will propose to answer the question: Can agent based simulation provide an effective methodology for use in decision making aided by dynamic modeling in order to provide higher system performance?

1.4. Goal of this Research

The goal of this research effort is to identify and develop a framework to predict workforce needs and trends that incorporates system complexity interactions and dynamic behavior models. Models are “abstraction of real or conceptual systems used as surrogates for low cost experimentation and study. Models allow us to understand a process by dividing it into parts and looking at how they are related” (Madachy, 2008). Therefore modeling can provide insight into the dynamic behavior of workforce variables as part of bounded process wholes. Interactions within a system composed of enterprise programs can be modeled and can be used by managers for improved decision making. An enterprise environment with a dynamic workforce, where work climate includes “employee demographics, project environment/management, accidents, human factors, and different systems architectures” (Marin et al., 2006), can be improved by modeling for system behavior modes to analyze different workforce planning strategies. The research aims to provide analysis of employee and managers interactions at different enterprise levels. Modeling of dynamic behaviors in work environments that generate units of information output that can demonstrate and further analyze the effects of changes in workforce strategic and tactical decision frequencies, planning perspectives and enterprise needs.

1.5. Research Objectives

- Development of a framework that enhances an enterprises workforce strategic planning based on its work environment complexity.

- Integration of methodologies to analyze work environment interactions and dynamic behaviors to complement the framework's modeling approach to manage an enterprise system.

- The ability to compare approaches that address workforce management and be able to determine changes and implementation of organizational changes in enterprise workforce management.

- Execution of case studies that test the framework to determine its success in simulating workforce management policies supported by analysis of interactions and dynamic behaviors of work environments.

1.6. Research Relevance

The research in this dissertation is relevant to enterprises where human capital planning and work environment interactions are keys to system performance. High Technical enterprises attribute success to their strategic thinking, concepts, innovations, and new ideas. In highly-technological organizations strategic planning is derived from various decision making periods and planning perspectives and different needs for information in resulting analyses and evaluations. The complexity and interacting behaviors among all management levels and enterprise engineering departments may have a large effect on their system management approach. The behavior of workforce environment components based on strategic decision and changes will be researched to determine if it becomes a relevant factor in workforce planning determinations.

1.7. Research Contributions

The research will develop and study a framework for decision making that will measure workforce demand and forecast, perform alternative selections, and analyze the dynamic behaviors of the workforce components. The framework will provide a way to establish a comprehensive decision-making methodology which managers may use to evaluate different workforce planning tactics. This proposed framework builds comprehensive, multi-resolution, and dynamic models of enterprise's workforce areas. Models are built relative to workforce climate, which includes human capital demographics, project environment, project management, human factors, enterprise safety, and enterprise system architectures operational/workforce requirements.

The main contributions from this research come in the form of:

- Workforce planning strategies based on complexity of work environment behaviors.
- Decision-Making methodologies based on the different dynamics linked with human capital mental models and various cultural issues.
- Alternative models for the enterprise's different dimensions of the workforce, especially at the strategic and at the operational levels of decision making.
- Dynamic analysis of proposed methodology made up of new workforce planning strategies, a combination of existing and new strategies, or where no changes are

beneficial for determining the effects of work environment dynamics and feedback in the overall enterprise system.

- Provide human capital managers and decision makers a way to measure the effects of alternative and/or complementary strategies in proactive planning to avoid and to transform negative workforce trends.

1.8. Thesis Outline

This dissertation is organized as follows: Chapter two reviews the existing literature to date as it relates to workforce management, workforce modeling techniques, system dynamics, agent based simulation, and the existing gaps in workforce modeling. Chapter three describes the flow of the investigation and the research methodology that the study will apply in order to improve decision making based on workforce management activities. Chapter four integrates the proposed methods into a framework approach and defines the framework's application. Chapters five and six apply the developed framework via a case study. Chapter seven will summarize, conclude and make recommendation on the research results.

Additionally, this research effort provides an user interface which management can effectively use to see where its workforce is going to be at any period of time. Workforce management personnel can use alternate approaches that include project requirements and financial limitations in order to plan and predict workforce needs and trends of the coming years.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

Workforce planning dates back to the mandatory reporting of skilled human capital levels in organizations required by the World War II Manpower Commission, (Cappelli, 2009). The idea behind this requirement was based on the prevention of shortages in human capital availability that may have negatively impacted the requirements for the production needs of the war economic effort.

Arguably, the emphasis on workforce planning was at its highest during the 1960's, back then 96% of the corporations were conducting workforce planning and forecasting functions. This percentage was said to have declined to under 20% by the mid-1990's (Cappelli, 2009). In 2009, Lawler reported that most executives who were surveyed on the subject of human capital indicated that even knowing that human capital was one of their most important assets, they found it very complex to make human capital a source of competitive advantage for their enterprises. Nowadays, the lack of workforce planning, the shortage of skilled resources and the cost of inappropriate requirement planning estimates, has prompted most business enterprises to pursue different human capital management approaches.

This research effort has encountered several techniques and approaches used in the handling of human resources. Specifically what business planners utilize to tackle assignment of personnel issues in different types of industries which include production enterprises, health related organizations, governmental organizations and even military entities. The methods used to accomplish workforce management tasks, according to the literature reviewed, range from operations research, to forecasting techniques, to artificial intelligence, and to soft computing techniques (neural networks, fuzzy logic, decision trees, etc.). It is important to emphasize that workforce management has features, (Findler et al., 2007; Huang et al. 2009) that have to be taken into account, such as the following:

- Uncertainty
- Complexity
- Numerous stakeholders
- Workforce components interactions
- Modeling
- Dynamic behavior
- Policy Change
- Multiple Resolution

This review also found that simulation methodologies are the most commonly used approaches to deal with tactical workforce planning tasks (Safaei et al., 2012), these techniques are regarded as powerful tools for the understanding of system behavior and for strategic evaluation.

This chapter presents a review of various methods which have been used to analyze and manage human components and in addition present three simulation modeling approaches, (Agent base simulation, System Dynamics and Discrete Event Simulation), that have been applied in workforce management to complement the techniques listed above.

2.2. Simulation

Simulation technologies involve the capture, representation and modeling of reality or of theoretical physical system enterprise. These modeling representations are executed and their results analyzed to assess the state of the systems. In 1994, Winston stated that, the resultant information found represents the different behaviors and interactions of humans, institutions and all enterprises' processes, units or divisions. According to Law and Kelton (1991), simulation processes unlike analytical techniques can't be solved using mathematical methods. They experimented with a system's performance modifying their parameters. Simulations are classified in three different categories:

- Stochastic: when model variables and parameters are probabilistic or deterministic when model "variables and parameters are known with certainty" (Budnick et al., 1988).
- Discrete: when model variables change only at discrete points in time or continuous for models that change continuously over time.
- Dynamic modeling of systems over time or static modeling of systems at particular points in time.

Simulation technologies have been regarded as powerful tools for the understanding of system behavior and for strategy evaluation. As described by Chan et al. 2004 and Brandelli et al. 2006, areas of production and supply chain that used mathematical models for their operations have adopted simulation as a complementary tool to enhance their operations, management decisions, logistics processes and human component-project assignments tasks.

In 2004, Stratman et al. simulated combining permanent and temporary employees at work. The result showed them that although there was a reduction in cost due to temporary workers, there was a hike on training and related quality cost.

In 2012 Safaei et al., stated that simulation is the most commonly used approach to deal with tactical workforce planning in highly stochastic environments. Their power restoration related research sought solution to workforce deployment to needy locations. The workforce demand is difficult to project in the electrical power domain under abnormal events (forces of nature). This group used simulation to determine the size of the teams needed to respond to abnormal maintenance issues and used simulated results to determine the optimal size of a permanent workforce that would satisfy task assignments under normal and abnormal conditions as well as the optimal size of temporary teams that might had been employed. Additionally, they were able to relocate workforce to cover manpower shortages under the abnormal events.

In 2009, Huang et al. concluded that workforce planning in human resource management is the most essential piece of the supply chain and services operations puzzle. This group debated the performance of solutions derived from workforce planning models due to the recognized fact that it is very difficult if not impossible to capture the human component behaviors using just mathematical models. In their effort, they used simulation based approaches to capture events characteristics and combined them with rule based models and optimization techniques to evaluate the efficiency and robustness of planning alternatives and task assignment rules (Huang et al. 2009).

2.2.1. Agent Based Simulation (ABS)

Agent based simulation requires that the domain/system to be simulated be modeled as a set of behaviors. This is an interaction based paradigm which has as main goal, a knowledge acquisition strategy that focuses on defining the behaviors of the systems entities and their interactions (Epstein, 1996). Agent based simulation introduces unique requirements for entities seeking goals autonomously. Entities have to be able to deal with uncertainty, to interact with other agents and their environment (Railsback and Grimm 2011, Yilmaz 2006), and to act in the absence of central behavior controls (Richiardi 2012).

The R&D area of ABS continues to bring new techniques for both real and imaginary systems in which a concrete problem needs to be resolved (Wooldridge, 2002). Research has found that although ABS seems a promising approach to complex systems where entities interact, the complete advantages of ABS and previous R&D is rarely used (Davidsson, Holmgren, Kyhlbäck, Mengistu, Persson, 2007). Research has designated as ABS end-users, scientists, enterprise policy makers, system managers, and other skilled professionals. "Scientists, use the ABS in the research process in order to gain new knowledge; enterprise policy makers use ABS in strategic decision making processes; system managers use ABS to make decisions at operational levels; and other professionals (architects, engineers, drafters, designers) use ABS in many of their project tasks" (Holmgren et al., 2009).

The main idea or purpose of ABS R&D design applications is classified according to prediction (making prognosis); to verification (to determine if designed models are correct); to train (improving resource's skills); and to analyze and get in-depth knowledge of subjects or domain (Wooldridge, 2009). Research regarding application of ABS has concluded that there are a certain number of domains which often involve interacting human decision makers (Davidsson, Holmgren, kyhlbäck, Mengistu, Persson, 2007). These domains include, social systems which are the most simulated ones while ecological/animal systems are the ones that were found to have the least amount of ABS applications developed about (Moss, Davidsson, 2000). Meanwhile, social systems (Hales et al. 2003), and organizations (Davidsson, Logan, Takadama, 2005), tend to be the ones that had shown the most applications researched and developed about over the last decade. Sichman, Bousquetand Davidsson in 2003 saw enterprises and organizations to be modeled as "structures of persons related to each other having common goals and accomplishing work or some other kind of activity". ABS applications in this domain (enterprise, organizational) aim to the evaluation of different approaches to personnel scheduling and activity tasks (Kafeza, Karlapalem, 2000), in order to accelerate the business processes and accomplish productivity goals (Sichman, Antunes, 2006).

Rouchier and Thoyer in 2003 defined social systems as those consisting of groups of humans with individual goals. These systems may turn out to have conflicting goals according to their social structures (Hadouaj, Drogoul, Espié, 2000). These systems are tied to economic systems which are organized with agents/actors (individuals, groups, or enterprises) that belong to organizations whose resources are active parts of a market sector (Robertson, 2003). According to Miyashita (2005) ABS applications which are to be considered under the economy realm, can be used in the analysis of all interactions and activities of entities in the system that will turn help understand how the economy changes/evolves/fluctuates over time. His observations also demonstrate how participants of the system, specifically workers, behave/react to the changing economic policies of the environment to which they belong.

This research has found that there exists several attributes that are characteristic of agents that ultimately contribute to the decision making purpose sought in this research. These attributes are:

- Learning from experience
- Bottom-up modeling
- Decentralize behavior
- Intelligence
- Environment perception
- Reaction capacity
- Interaction capacity
- Social ability

In 2002, Wooldridge defined, software agents as those agents which are assumed to be deterministic, environments are history dependent and non-deterministic thus agents make decisions based on the history of the system they are in. Additionally, we can look at modeling three workforce entity types: environment, company, and individual (Epstein, 1996). This setting can help the user improve his/her understanding of workforce dynamics and changes that take place at the organizational , essentially to see how changes in the style of the workforce could be matched to new business strategies (Forrester, 1961, Prasad & Chartier, 1999). ABS paradigms can represent different scenarios with respect to organizational transformations and their impact on the workforce without real world risks and consequences.

Shapiro in 2013, simulated workforce departures in government, using 2 agent based models whose purpose was to seek behavior of workers within an organization. His first model is not restricted by time and does not account for replacing workers but demonstrates grouping behavior by categorizing workers according to their level of satisfaction. His second model uses time and divides the workforce into age groups. It demonstrates the behavior of workers along their career stages and career path. He cleverly defines job satisfaction as the workforce intention to leave the job and the probabilities of staying at the job. He is able to establish turn over causes and associated characteristics that can be attributed to, as expressed by (Griffeth, Hom et al. 2000), the nature of the job, job satisfaction, workforce demographics, organizational and work environment factors.

Gilbert and Terna (2000) highlight how simulation has been adopted for organizational theory especially due to the development of agent based simulation models. Levitt in 2004, stated that these models link micro and macro organizational theories by addressing individual behavior designs and through validation on macro empirical data. Marks in 2007, complemented this statement by demonstrating how empirical validation of agent based models is performed at the individual and at the aggregate level.

Wilensky in 1999, introduced Netlogo to organizations that were dealing with workforce departure issues. According to Tisue and Wilensky (2004), Netlogo is a system that uses multi agent programming paradigms to deliver simultaneous instructions to large numbers of workforce agents. This system has been regarded as one system that permitted faster model design and that had the blessings of the academic community at the time (Robertson 2005). This type of modeling is based on Schelling's 1971's segregation model, it depicts the concept of workforce career stages and collective worker satisfaction. His model includes agent satisfaction preferences and satisfaction attributes that change according to the agent work environment. The model also depicts seeking behaviors, that allow for the formation of worker groups that evolve due to the actions/behaviors of the individual agent/worker creating 'neighborhoods' of agents (Shapiro 2013). Jain et al. in 2010 addressed issues related to manufacturing workforce managing and the need to use multi-resolution modeling in their approach. Modeling manufacturing components especially human components at different levels of details needed to be included in the system dynamics and agent based simulation to avoid time synchronization issues and components interactions.

2.2.2. System Dynamics (SD)

System dynamics is a modeling technique used in the quest to model behaviors of complex systems, issues or problems. These behaviors usually have interactions with each other over time periods. This technique uses specific methods to conceptually understand the structures of complex environments. It was created in the mid 1950's and started to be used in the 1960s with the creation of the MIT System Dynamics Group. Its methodologies have been applied in the management of business scenarios in the form of dynamic models that allow riskfree experimentation of alternative approaches and strategies. Sterman (2000)stated that, "System dynamics is also a rigorous modeling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations".   Bennet et al (2004) stated that the use of these techniques provides a detailed understanding of how a system really works and how a system would respond to specific actions. Managers can then use these techniques to model and analyze behaviors of systems and make improvements to their decision making.

"System Dynamics models the systems as feedback structures which generate complex dynamics. Models are represented in terms of two types of primitives, stocks and flows, and the relationships among them" (Forester, 1961). He stated that using differential equations and iteratively solving for them, this technique captures these relationships and generates the dynamics of the system. These modeling techniques can be used for testing changes in processes to affect system behavior based on sets of desired goals.

System Dynamics uses causal loop diagrams and stocks and flows (Sterman, 2000) to generate models. Causal loop diagrams describe variables linked by arrows which show the variable's influences on each other. The influences can be positive (reinforcing) and can be negative (balancing) feedbacks. Sterman (2000) stated that causal loop diagrams were like "maps showing the causal links among variables with arrows from a cause to an effect" and that they could only capture the dynamics of the system being modeled but could not describe the "stock and flow" structure of a given model. Sterman (2000) also stated, "Causal loop diagrams apply to the capture of hypothesis about dynamics' causes and to the demonstration of feedbacks of a specific process. On the other hand, stock and flow structures are descriptions of variables with rates or "flows" which can increase or decrease". "These flows accumulate into the most important information in a dynamic model as “stocks” which represent system states. Consequently, a well-built model needs variables for” (Cintrón, 2013).:

- the state of the system which are ”stocks”
- increase and decrease of these stocks (flows)
- linking stocks and flows which describe of the model behavior.

Using system dynamics methodologies for workforce resource management has been somewhat limited due to the fact that workers are much more difficult to deal with than are materials and equipment (Dietrich et al. 2006). Unlike other supply chains, the services supply chains rely more heavily on the human resource which has to be adjusted if it goes unused. Workers have to be acquired, release, trained, cross trained, given time and therefore incurring additional costs (Lee, Lianjun and Connors, 2010). These authors also note that these resources are bound to degrade as well, thru attrition, either voluntary or involuntary, partial or total. They additionally mentioned that these resource’s skills differ and change depending on experience and training thus making its management much more complex than simple inventory control. They take a good look at the demand and its fluctuations and apply the control theory to adjust the resource pool in the service industry. Their study concluded that by using feedback controls, a resource or backlog, oscillation reduction can be seen as well as a reduction on the amplified oscillation of the supply service stages in worker management.

Lee, Lianjun and Connors, (2010), stated that the Proportional, Derivative and Integral (PID), feedback control schemes could clearly be appreciated where there was a substantial demand increase and also where a demand change/oscillation occurred without any average net increase. The author’s conclusions and results are meant to help and provide useful information to decision makers in order to better manage their workforce. They plan to expand upon their findings in demand oscillations in several services fields.

Akkermans and Vos (2003) presented their observations of the services supply chain and its demand development effects. They dealt with a communication processes, and determined that the demand development effects were workload, work quality and rework and their interdependence. They also reported their experiences with the quality improvement applications to all stages of the supply chain and saw quality control as a valid measure to counter the effects of the amplified oscillation of service backlog.

Taking a look at the promotion model proposed in 2000 by Sterman, during his study of the growth and age structure of organizations, one can see that an important assumption was implemented, experienced resources may not be accessible due to a series of causes that may include high wages and unwillingness to participate in alternate task compromises. He continued with his 2000 study of labor force through a system dynamics approach considering learning curves, training on the job and mentoring set ups. He additionally studied workforce supply chain behaviors in alternative hiring and learning processes. In 1996, Coyle had used the same approaches while performing research in recruiting practices for new graduates and savvy consultants based on the job market potential of the time. His work was followed by Winch in 1991, with a propose human capital skill repository/management system to control the primary human assets, especially in organizational transition periods. Similarly, in the early 2000's, Hafeez and Abdelmeguid (2003) addressed company transitioning with a human capital skill methodology that would allow management to better understand the interactions and all dynamics involved in the know-how/intelligence/competence acquisition and retention. Hafeez et al. in 2004 continued to approach workforce planning problems with system dynamics but this time the focus was geared towards issues related to human capital recruitment shortages and surplus. The case study in question addressed the issues of a foreign petrochemical company's personnel loss and procurement. The idea was to provide decision makers the means to devise medium to long term efficient workforce planning strategies.

In military forces planning modeling, Wang (2005) approached the training challenge by using causal-loop analysis in the military officers system and complemented his work with simulation models using stock-flow diagrams of officer training system. In the manufacturing arena, according to Jain et al. 2010, the labor category refers to the stock of workforce available for manufacturing and the level of information available for this workforce. According to them, the higher the stock of trained in a given area of manufacturing the better it should perform. The workforce stocks may be treated individually or may be grouped into white collar, skilled labor, and unskilled labor.

2.2.3. Discrete Event Simulation (DES)

Discrete event simulation is a technique that models processes and/or operations of systems as a discrete sequence of events that occur over periods of time. The events of these processes occur at discrete moments/instants in the process and mark a change in the system's/process's state. Since there is no change between these events, then the simulated processes can advance in time to other events that occur in the processes.

A top characteristic of discrete event simulation modeling processes according to Griffin and Skinner (2003) is that it allows parallel, distributed, and interdependent flow across a system. It also allows tracking and estimates of performance of system's entities (Venkateswaran, Son & Jones, 2004). This approach was used during the modeling exercise of critical decisions timeline performed by the crew of the USS Vincennes (Franceschini, McBride, & Sheldon, 2001), therefore it is assumed that some important managerial emergency decision activities such as, workload, priorities, saturation, timeline and service time could be modeled using discrete event techniques.

In 2005, McGinnis presented the organizational world a different perspective for simulation. He proposed the use of knowledge acquired from integrated circuits design and from discrete event logistics systems. He stated, "in terms of design features, a contemporary integrated circuit is clearly a more complex artifact that could be contemplated." McGinnis pointed out that since circuits have many levels of abstractions, the lower level provided a set of bases and simple functions, there was a chance that a discrete event simulation model could be used to predict behavior of human components in logistics operations.

McGinnis (2005) also emphasizes that after all discrete event logistics systems are not completely formalized processes and lack a formal modeling discipline. He states, "Nevertheless a large portion of the organizational simulation problem domain consists of organizations which exhibit discrete events of materials, workforce, or information, and whose behavior over time is intimately related to these events."

In the call center domain, discrete event simulation practices have taking place using contact center modules to allocate customer service representatives. Here the managers can meet the call rates by satisfying the required demand through efficient scheduling and performing "what if" scenarios of changing call volumes at different periods of times and seasons.

In terms of integration of simulation techniques for system processes and interactions, let us now look at two instances that show the integration of two simulation paradigms in a manufacturing systems environment. These applications depict significant techniques which could be modeled for representations of managerial organizational personnel processes and physical systems. For the first instance in 2000, Biswas and Merchawi provided details of their implementation of a discrete simulation model that was run in conjunction with an agent based scheduling simulation engine. They were able to validate adaptive workforce scheduling using a discrete simulation software package that simulated several factories. They introduced several controlled input parameters that were sent through, from a message broker to an agent based scheduler. Inside this scheduler, several agents were capable of making decisions based on their own individual set of priorities and rules.

For the second instance, Venkateswaran, Son and Jones (2004) had a model of a hierarchical production plan using a planning level, which was a higher decision level, and a scheduling level which was a lower decision level. This hybrid approach had a system dynamics part that simulated the production dynamics involved in the execution of the production plan and a discrete event model that simulated the operations plan (human resources, material processing, transfer, and storage). This interaction was accomplished using a high level architecture. The accomplishment demonstrated how a hybrid simulation framework can provide a seamless integration of two different simulation techniques that provided means to the analysis of interdependent processes in a factory system setting.

The literature search showed that the most complex model found based on a discrete event simulation approach to systems simulation was "A Study on the US Expeditionary Warfare System", conducted at the Naval Postgraduate School (2003). It emulates an expeditionary force which is defined as a system of systems. This model represents entities for ships, aircraft, vehicles, fuel, food, and water, which are connected within the system environment. The model simulated provided bases for: 1) system of systems analysis of expeditionary warfare architecture; 2) the study of interfaces and synergies among warfare entities and systems within the organization; and 3) comparing different operational concepts for troops, vehicles and logistics support. Additionally, knowing that the two models built provided significant knowledge about how to approach the analysis of military organization in a dynamic environment, it is important to point out that the system had some laws and limitations. To start with, the model required user inputs, it had no optimizations and it generalized some assets and resources into arbitrary categories.

Another military model that caught the attention of researchers is the one by Flournoy and Murphy, 2002. It is a warfare simulation that has a discrete event simulation system built under an organizational approach. The system simulates communications required during civil and military crisis events. This architecture is supported by commercial off-the-shelf software. It is made up of a set of libraries, a scenario builder, resource planning capabilities, a simulation engine, and various analysis tools. It uses entities to simulate communication equipment, organization resources, and information.

In the field of aircraft crew planning, discrete event practitioners considered the schedule planning disturbances originated by aircraft issues, personnel availability and departure arrival changes as well as crew rotation and even weather related issues. Lettovsky et al. (2000) considered the problem of reassigning airline personnel to try to mitigate the existing schedule problems. During that same year, Rizzoli and Takahashi used the same discrete event approach to model rail and road transportation.

The SimMan, a discrete event simulator developed by Huang et.al. in 2009, is a system that permits the evaluation of different planning alternatives/policies and assignment strategies.

The models developed can be compared with one another in terms of their effectiveness and identification of best production planning strategies. The system uses human component profile information and categorizes it as events. Such information is input into the system as: training events, departure and arrival events, and as future assignment events.

2.3. Workforce Modeling Techniques Other Than Simulation

Considering labor challenges during the early 21st century decade, technology advancements are expected to play a major role especially in terms of adoption and acceptance. As presented by Judy and D'Amico (1997) as part of the Hudson Institute's report, although new technologies may bring a feeling of discomfort, intrusion and change, their overall adoption trend will in the long run certainly create more opportunities for an enterprise's human capital than the number that it will limit or destroy.

The Management of a workforce includes all the activities needed to maintain its productivity. Nowadays, the concept of workforce management has evolved into optimizing all markets and industries, through the assignment of the right employees with the proper skill set to the right tasks and at the right time (Clapperton, 2010). According to Wang (2005) and Charness, (2008a, 2008b), the technological applications developed for workforce management and optimization have gone beyond supply chain management, production planning systems and enterprise resource planning. Applications are now vital strategic ingredients needed for the corporate recipes, mixes and approaches of successful management.

Today's literature shows us that research in the field of strategic workforce planning and management is more relevant with respect to and geared to the issues that are being solved for a particular enterprise field. These research approaches can be undertaken as deterministic and stochastic models, additionally, these models are designed to manage homogenous as well as heterogeneous enterprise workforces.

Through the years, workforce management practitioners have successfully applied its concepts to the areas of resource: staffing; productivity; allocation; and utilization. Their extensive research has also touched the areas related to workforce planning/managing and cross-training issues, for instance, scheduling a workforce with different characteristics and qualifications (Billionnet, 1999, Ebeling,Lee., 1994). Some in academia, (Steward et al., 1994), used integer programming and optimization models to minimize labor cost, to determine assignments according to skill levels for different scenarios; others used different hierarchical methodologies to find optimal operator assignments as did Suer in 1996. Wee in 1999, used integer programming models that optimally helped determine optimal training policies where his designed models included how the demand fluctuates overtime. Lee et al.(1997) and Winch (1999) used optimal algorithms in their research to minimize requirements and cross-training related costs. In 1991, Lockus and Jacobs used heuristics to perform minimization tasks of resource assignments; their study was based on worker qualifications and their availability. On the other hand, Vairatakis et al. in 2002, used heuristics as well for job shop scheduling. Both of these approaches in each case concluded that using heuristics resulted in near optimal executions.

In 2009, Shulka proposed a decision support model to carryout workforce managing and forecasting in a more efficient and effective manner. His decision support model worked using selections trees to identify the workforce parameters, prepared workforce related questionnaires for subject matter experts and used those answers and fuzzy logic to integrate and analyze the experts' responses. Finally, he used a clonal c-fuzzy decision tree for forecasting the workforce. The author recognizes that decision trees are not used much for the forecasting of future workforce, his models ended up developing a new decision tree approach for workforce forecasting.

Operations research approaches to workforce management include a realm of objective functions and constraints to face the ever popular shift scheduling and task assignment projects. In 2001, Nembhard used heuristic approach in order to assign human resources to different tasks accounting for their learning rates, the results showed overall productivity improvement. In 2002, Kostreva et al. approached human factors modeling design issues with optimal shift assignment approaches. Their final strategies showed the effectiveness of the selected strategies. For Malladi and Jo Min in 2004, it was more beneficial to approach scheduling using the Analytic Hierachy Process (AHP), they wanted to assign weights to different scheduling schemes. Different working arrangements were taken into account in terms of forward vs. backward schedule rotations. Schedules that were considered more disruptive to the employee physical, mental and behavioral state were assigned bigger penalties (cost) by the weighing AHP scheme. The final weighing results were entered into an integer programming model that produces the optimal solution for the desired shift scheduling strategy and policy.

Corominas et al. in 2010, tackled the assignment endeavors with minimal completion times as goals, using a linearization technique to deal with the non-linearity of the performance function of scheduling. Here the research team sought to account for the impact of ergonomics in scheduling but could not represent or even set human resources characteristics. In 1992, Chen and Yeung integrated expert systems and goal programming in attempts to solve medical personal scheduling conflict issues. Kostreva and Jennings in 1991 and Malladi and Jo Min in 2004, approached the issue by presenting a shift generation algorithm/method that considered the physical, mental and behavioral changes of personnel. Additionally, the methodology took into account constraints such as time off between shifts; number of consecutive workdays; and shift frequencies during two-week periods.

2.4. Summary and Gaps

Most literature in Workforce management historically assumes that workers are identical but fundamental decisions in workforce planning must assume the workers are inherently different; managers should outline and be able to measure individual worker differences.

Additional literature was found related to workforce planning and cross-training costs during the research performed by several other scientists among which we find: Brusco and Jones, 1998; Campbell, 1999; Cordery, 1989, Judice et al., 2005; Bard et al. , 2003; Caprara et al, 2003. Alternative research has been done using heuristic methods, such are the cases of: worker assignments to minimize overstaffing based on qualifications and availability (Lockus, Jacobs, 1991); minimize job shop workforce size and production cycles (Viaraktarakis et al, 2002). Studies on system performance and cross-training, have been done using simulation, for instance to study the benefits of improving process flexibility (Felan et al, 1993); studies on the concepts of multi-level flexibility workforce (Felan, Fry, 2001), results showed that combinations of high flexibility and no flexibility are less costly than a workforce with equal flexibility; server utilization and efficiency on the optimal workforce mix (Agnihothri et al, 2003).

Research performed by Dooley in 2002, has shown that discrete event simulation is not appropriate to use when state variables interact with one another on a continuous basis, and when systems' entities and their internal mechanisms are a more important element of the simulation than an event. Although this approach collects information and characteristics of system entities, is not enough for capturing all of the characteristics of entities and the system itself.

Agent based simulation concepts have been successfully applied to a diverse number of areas. In each of these areas, agents react to one another and to the environment and have the capability of learning. It is a technique that has not been applied to the workforce area and its concepts have not yet had an impact. Since, “Agents are programmed software modules that scan their environment and make decisions” (Ilanchinski, 1996). It is the intention of this research to take agents attributes in a workforce setting and use them to help in the managerial/technical decision making processes.

Moreover, optimizing a component system in which all the members have individual and potentially conflicting objectives is something that has not been largely investigated (Shah, Pritchett, 2005) . This is the area where system dynamics and agent based simulation should play an important role in modeling the enterprises’ workforce in the short, medium and long term.

By analyzing the state of an enterprises’ workforce through system dynamic approaches and methodologies, this research effort seeks to capture and extract the main characteristics of human capital and overall enterprise resources and use them in an agent based simulation setting to design methodologies that can contribute to strategic enterprise planning.

In summary, after reading through the literature studied and reviewed, this research effort has found that in terms of dealing with workforce management features; there is not a comprehensive approach that takes into account uncertainty; complexity; and workforce component interactions; that models and analyses behavior thoroughly; that analyzes the state of an organization’s workforce and its components; that optimizes organizational policies and that analyses the workforce at different resolution levels. This research effort uses systems dynamics modeling and agent based simulation in order to account for system component complexity and to provide an organization with optimal policy strategies that include the analysis of : human capital available, overall enterprise resources, and work climate dynamics.

Table 2-1 presents a synopsis of the reviewed literature and the research gaps as related to workforce management approaches. The table summarizes the methodologies used by the author in an enterprise's workforce analysis and management.

Table 2-1. Literature Review

	Workforce Management Most Important Features						
Authors	**Uncertainty**	**Causality**	**Multiple Components**	**Complex Relationships**	**Dynamic Behavior**	**Multiple Resolution**	**Workforce Management Approach**
Corominas et al., Claperton, 2010			×				WFM Technology Applications other than simulation
Wang, 2005; Charness, 2008			×				
Steward et al., 1994; Suer, 1996			×				
Lee, Viaraktarakis, 1997			×				
Lockus and Jacobs, 1991			×				
Vairatakis et al. in 2002			×				
Ebeling,Lee. 1994; Winch, Viaraktarakis, Bilionet, 1999			×				
Epstein, Axtell, 1996; Sosa, Gero, 2003			×		×		Agent Based Simulation
Wooldridge, 2002,2009			×	×			
Davidson et al., 2007; Miyashita, 2005			×	×			
Shapiro, 2013			×	×	×		
Griffeth, Hom et al., Gilbert and Terna, 2000			×		×		
Jain et al. 2010			×	×		×	
Marks, 2007			×			×	
Prasad, Chartier, 1999			×	×			
Wilensky, 1999			×	×			
Tisue and Wilensky,Levit, 2004			×	×			
Robertson, 2005			×		×		
Safaei, 2012			×				Discrete Event Simulation
Sichman, Antuness, 2006			×				
Huang et.al. in , Huang, 2009			×				
Rizzoli and Takahashi, Biswas, Merchavi,Lettovsky et al., 2000			×				
Flournoy and Murphy, 2002			×				
Griffin, Skinner, Naval Post Graduate School, 2003			×				
Francesshini etal., 2001; Venkateswaran,et al.,Venkateswaran, Son & Jones, Venkateswaran, Son & Jones 2004			×				
Wang, 2005	×	×	×				System Dynamics
Hafeez et al., Bennet et al, 2004	×		×				
Winch, 1991			×	×	×		
Coyle, Dietrich, 2006			×	×	×		
Sterman, 2000		×	×	×	×		
Akkermans, Vos, Hafeez and Abdelmeguid, 2003		×	×				
Lee, Linjaun, Connors, Jain et al, 2010	×		×	×	×		
Marin, Rabelo, 2014	×	×	×	×	×	×	**Workforce modeling approach using System Dynamics and Agent Based Simulation**

CHAPTER 3. RESEARCH METHODOLOGY

Chapter three outlines our research design and methodology that this effort is based upon. It discusses the rationale behind the selection and explains the process implementation. This research's purpose is to explore the culture, nature, characteristics, challenges, opportunities, climate, and the crucial and most important factors of workforce environment internal to the enterprise's operational systems context.

3.1. What is a Research Methodology

Research methodology is a systematic, theoretical analysis of approaches and methods applied to a field of study. It includes paradigms, theoretical models, different phases and quantitative or qualitative analysis techniques. Researchers use a certain methodology as a guide to understanding the best method to be applied to solve an specific case. It could also be portrayed as the analysis of principles and applications of rules for certain disciplines

3.2. Research Methodology

The investigation begins with a statement of the research question. The research to be conducted starts with a recommendation for improving workforce prediction based on work environment analysis. Decision making and analysis of management policies and performance of enterprise systems are complex processes that can benefit from structured analysis approaches. To implement and execute effective policies, change management must take into consideration the interactions that human capital and enterprises' work climate have among them. The investigation asks the question--can combining a methodology for agent based simulation and modeling of dynamic behaviors provide an effective approach for use in decision making based on work environment complexity? This question will be researched by studying two methodologies in an integrated framework that aims at predicting workforce needs and trends. The potential contribution is the structured combination of agent based simulation and dynamic modeling to analyze enterprise work force environments. For the purposes of this research, enterprises consist of complex workforce environment interactions and of enterprise systems dynamic behaviors. This research will then answer the question--can workforce environment analysis provide better approaches for decision making based on work environment modeling and agent based simulation?

The research is introduced for decision making based on process change interactions and feasibility and adding a major contributor in modeling workforce environment for effects and stability (Chapter 1). The literature review in Chapter 2 compares methods to answer the research questions and describes units of analysis derived from workforce environment complexity that will become the basis for workforce environment modeling in the proposed framework. These units of analysis will be the pre-cursor to developing the framework, which starts with baseline (current) and proposed (alternative) workforce environment approaches for structured strategic planning and eventual dynamic modeling (Chapter 4). A case study will be executed to put the framework into practice (Chapters 5 and 6). An analysis of the framework based on case study results will summarize the completion status of the research (Chapter 7). The research methodology is depicted by Figure 3-1.

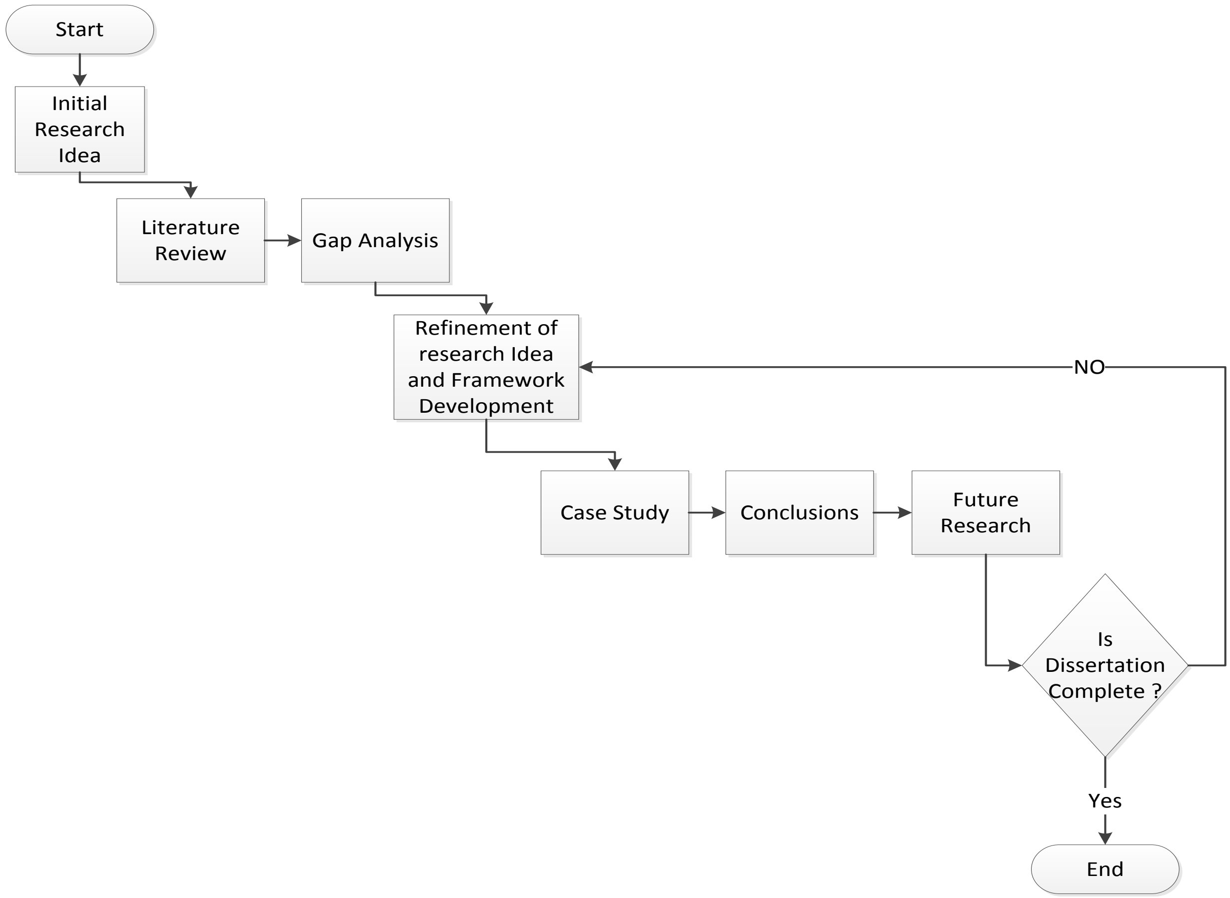


Figure 3-1. Dissertation Methodology

3.3. Initial Research Idea

The research methodology starts by stating the research question. This investigation begins with an inquiry of the need for providing enterprise workforce strategic planning based on its work environment complexity. The research begins by asking--does analyzing an enterprise workforce and concentrating on modeling work climate interactions, (because they provide detailed characteristics), affect the overall system management approach? How does adopting strategic planning policy changes, affect workforce prediction? These questions lead to the main research question--can agent based simulation provide an effective methodology for use in decision-making when aided with dynamic modeling to provide higher system performance?

3.4. Literature Review

The literature review showed that the lack of proper workforce planning, the shortage of skilled resources and the cost of inappropriate requirement planning estimates, has prompted most business enterprises to pursue different human capital management approaches. In consideration of the present day labor challenges, technology advancements are expected to play a major role especially in terms of adoption and acceptance of workforce environment complexity studies and analyses as the basis for predicting workforce needs and trends.

The literature additionally described the need for managing the change processes in human capital management so that managers can identify critical interactions among workforce components to anticipate how to implement change, in what order changes can take place, and if the proposed changes are stable and coherent. Along with the need for management of change, the behaviors of workforce enterprises methods and policies functioning as part of enterprise systems need to be considered after changes are implemented. The review and analysis focuses workforce analysis and dynamic interactions between workforce enterprise components.

3.5. Gap Analysis

Workforce strategic planning has been based mostly on activities needed to maintain productivity, it has evolved into optimizing all markets and industries, through the assignment of the right employees with the proper skill set to the right tasks and at the right time but approaches are not as effective analyzing work environment interactions and dynamic behaviors within a work environment. The major contribution of using workforce analysis to predict workforce management needs and trends is the application and integration of methodologies to analyze work environment interactions and dynamic behaviors.

With available alternatives that may improve workforce strategic planning, the ability to anticipate complex interrelationships surrounding change within an enterprise becomes significantly important. Merely introducing changes that may affect the work climate would be incomplete without understanding things such as stability of changes, sequence and pace of implementing change, and human capital opinions. There is a need for analyzing the interactions that work environments have within their systems and the applications of workforce management technologies to date have not considered this. Systems demonstrate behaviors based on processing of inputs to generate outputs and these behaviors can complement or affect each other. Merely analyzing workforce metrics does not achieve comprehensive decision making. The need exists for enterprise management and human resources managers to thoroughly analyze their workforce and assess its state, then model said workforce to be able to see its state in the future.

To conclude, according to the literature reviewed, this research effort has found that in terms of dealing with workforce management features there is not a comprehensive approach that takes into account uncertainty, complexity, workforce component interactions that models and analyses behavior thoroughly, that analyzes the state of an organization's workforce and its components, and that optimizes organizational policies and that analyses the workforce at different resolution levels. This research effort uses systems dynamics modeling and agent based simulation in order to account for system component complexity and to provide an organization with optimal policy strategies that include the analysis of human capital available, overall enterprise resources (e.g., budget, projection, project manifests), and work climate dynamics.

3.6. Refinement of Research Idea and Framework Development

The literature review demonstrates that the prediction of workforce management needs and trends can be accomplished through the incorporation of system complexity interactions and dynamic behavior models. Complex systems modeling can provide insight into the dynamic behavior of workforce variables as part of bounded process wholes. The interactions within a system composed of enterprise programs can be modeled and can be used by managers to achieve improved decision making for workforce strategic and tactical decision frequencies, planning perspectives and enterprise needs.

The development of a framework that considers human components characteristics and planning requirements can greatly enhance an enterprise's workforce strategic planning based on its work environment complexity. This research effort will propose that interactions and dynamic behaviors in a work environment, facilitates a important improvement in decision making. The focus of this effort is to design and develop of a framework that facilitates the analysis and decision making processes for any workforce. The investigation will present a structured approach to workforce strategic planning based on work environment complexity along with work environment interactions and dynamic behavior.

From the literature review it can be concluded that the following steps need be considered to accomplish the goals of the proposed question:

1. When considering alternatives in the development of effective workforce planning strategies, select areas of the workforce enterprise need to be analyzed.

2. Obtain workforce environment component metrics based on enterprise system complexity to determine the individual value of each component.

3. Analyze workforce component interactions at strategy and operational levels for how complementary and stable the components are when combined as part of an enterprise system.

4. Capture and extract the main characteristics of human capital and overall enterprise resources and simulate the enterprise setting to design methodologies that can contribute to strategic enterprise planning.

5. Model the behavior of the enterprise system to determine cause and effect of workforce planning strategies in an enterprise environment and study the dynamics of strategic policy changes.

The important factors that influence workforce management are defined from the literature review; these include internal and external factors that affect the work climate. From an internal perspective, enterprise particulars, we can detect: workforce readiness (education, skill and experience, competence), retirement availability of the workforce, demographic profiles of the existing workforce, the labor union relations that act upon the work environment, the existing organizational support, turnover rations, the financial state of the organization, wages, and the relations and status of the enterprise leadership. From the external factors perspective, there are many that have to be considered for analysis of the enterprise workforce. These factors range from its demographic diversity, the economic conditions of the area and the economics of the business cohort, the technological advances embraced by the enterprise technology groups, the political and legal aspects of all operations, the relational interactions of employees-customer-competing enterprises, the government policies and laws that apply for such a business line.

There are some performance indicators that also influence the workforce policies and strategies evaluate the existing components of the studied workforce. These indicators include program completion and success, safety aspect at the enterprise facility, the operational efficiency and effectiveness of the programs in place and the satisfaction of the variety of customer that the enterprise has.

The features of workforce management are studied, analyzed, and characterized into the most important features including uncertainty; complexity; workforce analysis; workforce component interaction; modeling the dynamic behavior; and the enterprise policy change practices. The complexity of these features drives the difficulties of transforming an enterprise operation toward the optimal workforce mix. In addition to the research gaps discovered, there is a need for a proper framework that facilitates the decision capabilities of management to detect when, why, where and what changes to strategic workforce plans are needed.

This research effort has established a framework mapping (Figure 3-2), that represents an approach to develop a new decision-making framework for workforce strategic development. The most important features of workforce management can be analyzed and evaluated by using dynamic behavior modeling, agent based modeling of the workforce components and the adoption of new strategic plans as needed.

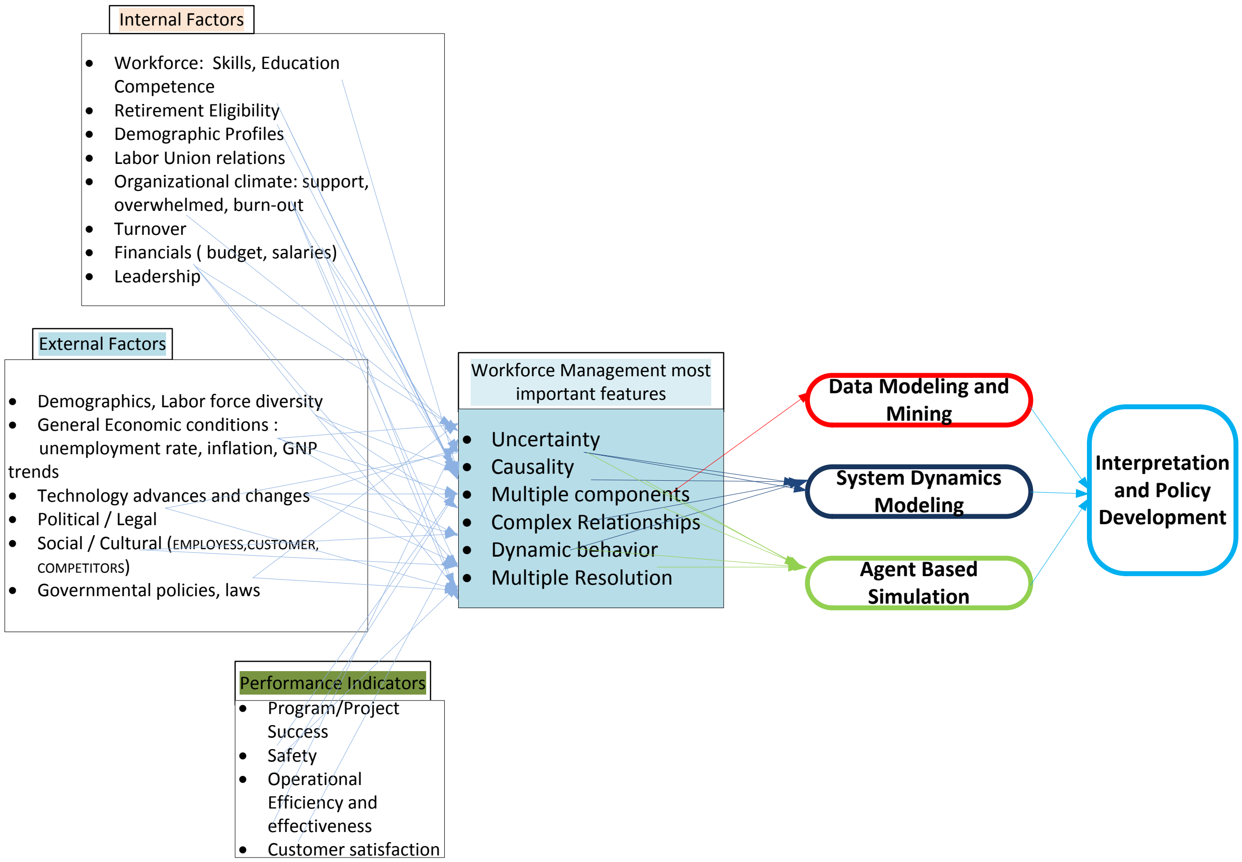


Figure 3-2. Framework Mapping and Development

3.7. Case Study

The enterprise chosen for this study is the National Aeronautics and Space Administration at Kennedy Space Center (NASA KSC). For its workforce enterprise, planning and productivity are important concerns.

There exist many internal and external factors that have effect on the enterprise. “In order to manage human capital in a manner consistent with safety and mission success, and to strategically position the center to execute its future mission, it is necessary to understand how all of these different influencing factors work together to produce an overall workforce climate”(Marin et al. 2006).

These factors can be categorized as internal and external. External factors include the cost of living in the Central Florida area, the availability of skilled technical prospect employees, and also the unemployment rate effect through the workforce climate at NASA KSC. Internal factors such as re-organizations, the emphasis on “doing more with less”, the increasing changes agency wide, the additions of new vehicle and launch programs (Figure 3.), the higher pace of technological change, the uncertainties in new and old projects and the complex and conflictive economic forces have prompted the need for development of challenging and effective workforce planning strategies. In the process of dealing with this challenge, motivating the workforce is the decisive hurdle to overcome in a highly demanding technical and fiscal environment. In order to ensure mission success at NASA KSC, it is important to develop integrated human resource policies and align the organization accordingly. The development of strategic planning models, organizational learning, and experimentation will provide the organization with this ability (Marin et al., 2006).

Based on the framework of section 3.6.this case study will help validate our research questions. Figure 3 depicts the NASA KSC enterprise. This type of framework may help promote organizational planning to achieve effective workforce planning strategies to accomplish the required vehicle launch rates and mission success. It is this research’s intent to enable the Human Resources Department and NASA KSC Management to understand the workforce climate and forecast trends that may lead to unsafe working conditions.

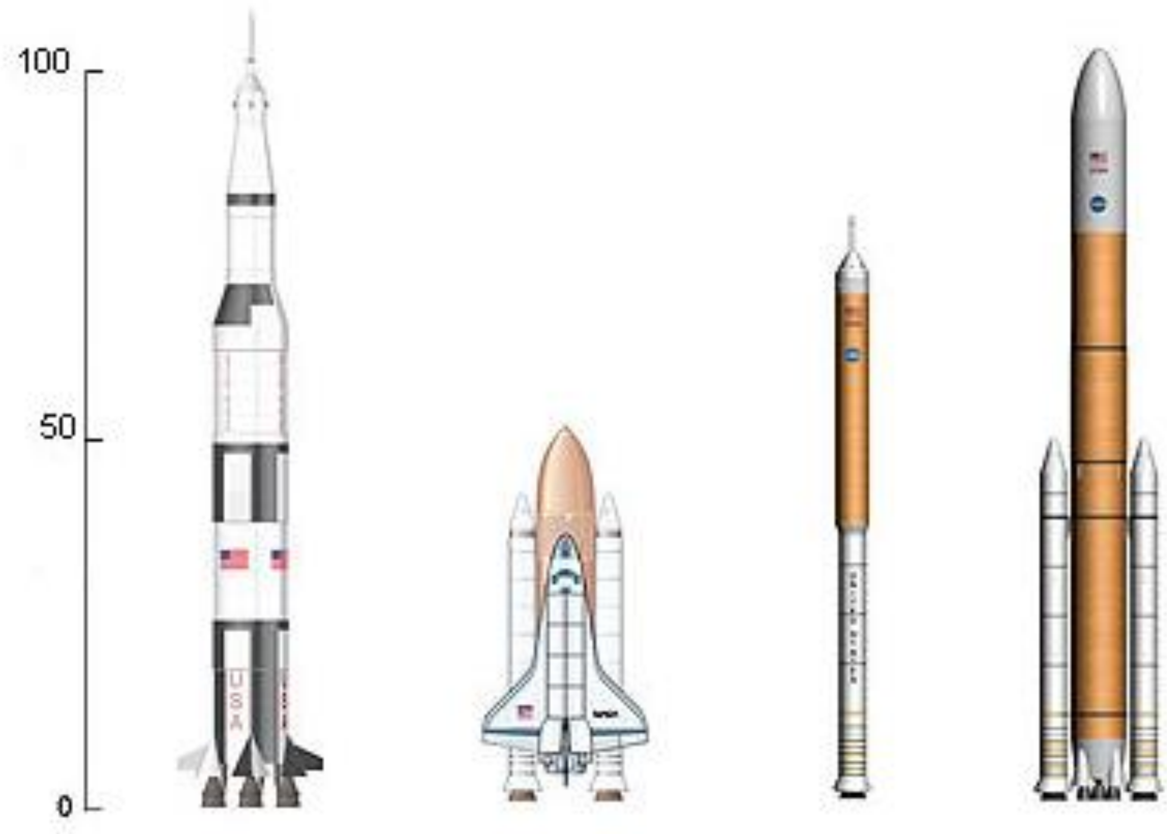


Figure 3-3. NASA KSC Space Program Vehicles

The proposed models intend to help manage the transition between the different launch vehicle programs as the workforce experiences the necessary reassignment to meet program requirements.

After the boundaries of the system and its core areas of interaction are selected and defined, the metrics to be collected will require assessment of the impact of management strategic actions. Therefore the metrics will be based on workforce components interaction behavior results along with appropriate defined strategic measures of performance. The system modeling will consider the workforce component dynamic behavior.

The goal of the case study is to propose alternative policies and compare them with current policies in terms of workforce performance metrics which will be measured for a baseline state and for a state where policy changes/improvements are made. The analysis will compare the baseline policies and alternative/proposed policies, reviewing results for accuracy, effectiveness and refining the framework as required from analysis findings.

The case study will undergo a series of phases which range from definition of workforce environment boundaries to the analysis of the simulation results (Hung-Da et al., 2011). After the analysis, the results should reflect the following benefits of the proposed decision framework:

(1) facilitate increased workforce flexibility, facilitate improved workforce trend predictions, and facilitate more information to managers and all decision makers;

(2) evaluate alternative strategic plans in relation to workforce climate uncertainty;

(3) gain new understanding of necessary changes and operational innovations; and

(4) help develop and validate our framework

3.8. Analysis and Framework Evaluation/Modifications

The developed framework will be used to demonstrate, by the application of the case study, the framework's functionality. The case study will apply and exercise the framework to show how the framework performs the proposed objectives.

The next step studies cohesiveness and interactions between all workforce components. The framework will use this as a preliminary evaluation of components behaviors to determine if further consideration should be given. The analysis will allow decisions that can range from no changes (to maintain current strategies) to changes on all workforce policies. The interaction analysis will yield methodologies to compose a modified enterprise system which could be made up of any combination of current policies and proposed policies. After workforce components are selected by studying how complimentary workforce components function in a system, the newly defined system is studied for how workforce components behave with each other and how they affect the entire enterprise system. The framework application phase of the research methodology will take place as shown in Figure 3-2.

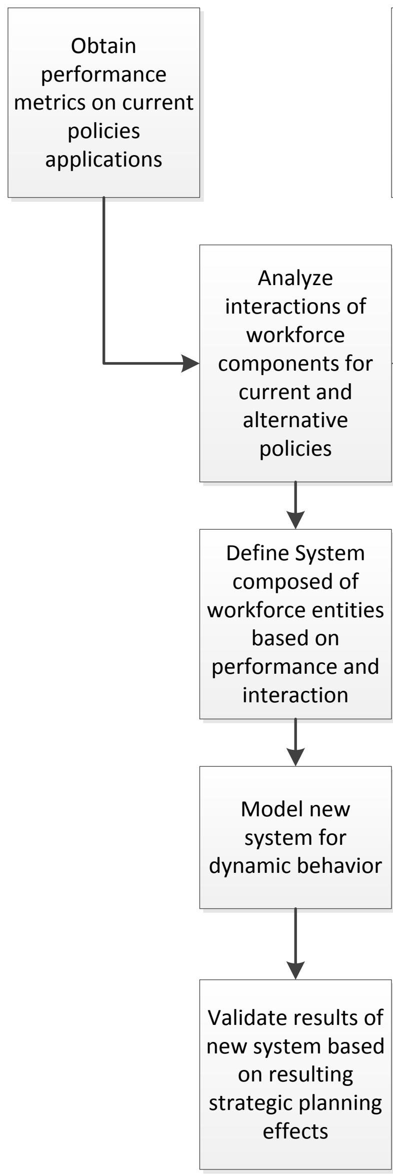


Figure 3-4. Framework Application Flow

An analysis of results (with possible need for framework revision) will describe the findings from the study of the new policies selected using the framework. If the results cannot be validated, the framework will require revisions to reattempt the expected goals. The proposed framework starts with the analysis of workforce enterprise complex interactions. It defines an appropriate technique for gauging workforce components performance. It then facilitates the study of alternative workforce policies based on component interactions, their characteristic's feasibility, and the system robustness once policies are modified and applied. The proposed framework then provides the design of workforce environments models' structures and feedbacks. At the same time, it applies a metrics methodology. The literature found does not allow workforce component interactions analysis processes prior to any changes nor does it provide analysis after changes take place, it then disregards controlling and comparing workforce component variables. In order to meet the dissertation goals the framework will be exercised on a case study of enterprise workforce climate to test the framework's validity. This validation will provide the ability to assess intangible benefits to provide better allocation of enterprise resources through proactive strategic planning for productivity and value of an enhanced enterprise.

3.9. Conclusions

This investigation's proposed framework will benefit communications between an enterprise's top level and lower level decision-makers. To this extent, this research suggests that the resulting and adopted critical plans be subjected to periodic adjustments and modifications according to the feedback that will be provided by the lower level decision makers. This method will absolutely increase the receptivity of the workforce enterprise and will increase and enhance the ability to yield proactive planning in order to avoid and to transform negative workforce trends.

3.10. Further Research

The proposed framework intends to demonstrate the integrated use of systems dynamics methodologies and agent based simulation to improve workforce management decision making. In order to continue improving the proposed methodologies for additional research we will study potential research areas.

CHAPTER 4. FRAMEWORK

The framework for this research effort will be the use of work environment interactions complexity and dynamic behaviors of enterprise systems as the method by which enterprise programs can be modeled and can be used by managers to achieve improved decision making for workforce strategic and tactical decision frequencies, planning perspectives and enterprise needs. The research seeks combine structured methods and approaches in an ordered manner for a framework which is capable of analyzing workforce strategic planning based on work environment complexity along with work environment interactions and dynamic behavior. The framework will improve the process of alternative selection in the development of effective workforce planning strategies and supplement it with analysis of interactions prior to changes and the dynamics taking place after process changes.

Initially, we seek to accomplish the development of causal loops where all the interdisciplinary enterprise groups are to participate. Several meetings and storm brain sessions are to take place to elicit the necessary information. Causal loops will be validated and modified accordingly. This information will serve as basis for the system dynamics models of workforce enterprise interaction. These models will facilitate the design and creation of alternate strategic policies. After the selection and implementation of alternative workforce management strategic plans, these plans are to be applied and the workforce will be simulated and analyzed to assess the change implications from existing strategies to results of proposed strategies.

This chapter outlines this research's workforce enterprise problem definition, describes the proposed framework, describes in detail the data analysis (data mining) and modeling techniques to be utilized (causal loops, stocks and flows, agent based simulation) and finally describes the types of results expected during the investigation effort. Figure 4.1 shows the flow of the proposed framework.

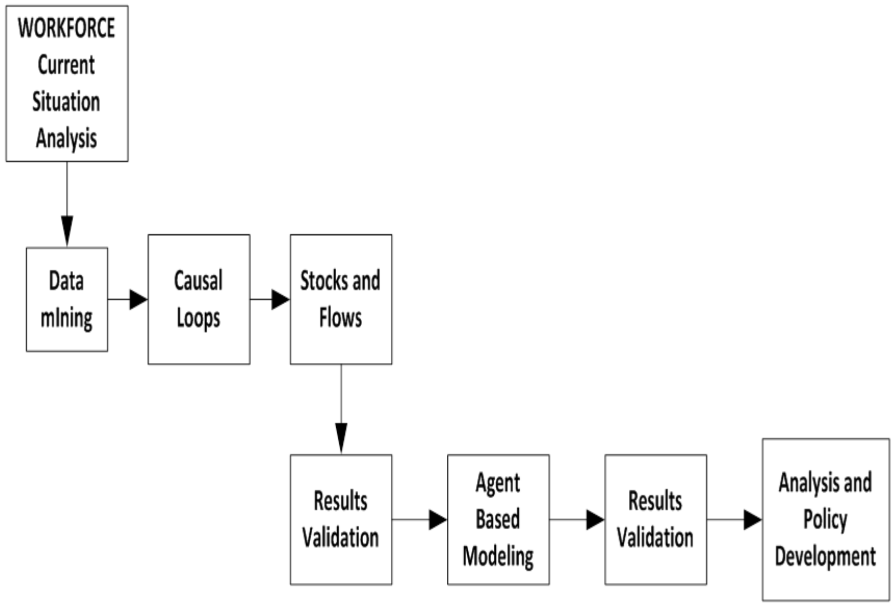


Figure 4-1. Proposed Framework Flow

4.1. Problem Definition

With the realization that technical business enterprises that perform either project or non-project activities there is an implied need to implement different decision making policies and planning horizons. Additionally, these enterprises need a continuous assessment and analysis of the different needs of their workforce. Additionally, interactions and cause-and-effect relationships among an enterprise's management levels and the different engineering units/departments have to be taken into consideration for the modeling and the analysis processes of the performance of the overall enterprise system. (Marin et al., 2006)

4.2. Analysis of Current Situation

The framework being developed has a starting point which includes the analysis and study of the workforce state and its current strategic plans. Then a selection takes place of those procedures that could be under consideration for change or improvements. The procedures will be evaluated for fittingness to measure their viability of allowing change and implementation.

Analyzing the current situation of an enterprise's workforce is one of the most crucial phases needed for effective workforce planning. It is composed of the following tasks (Hung-Da et al., 2011):

(1) to analyze the demand in order to predict the number of employees needed and the workforce composition, competencies and skill levels needed to match future business requirements;

(2) to analyze the existing human component competencies and aptitude level profile and the envisioned profile in the future based on the current workforce needs and trends;

(3) to compare the existing workforce and the business projects/program projections to determine competencies future human capital shortages and surpluses;

(4) to develop strategies that allow an appropriate procurement, development, performance, retention and departure strategies and projections to undertake the most important issues that can ensure that the enterprise has a adequate workforce base to meet future challenges and needs.

4.3. Data Mining

The framework flow continues with the application of data mining techniques to extract information related to organizations workforce components. It is needed in order to identify the characteristics of all parts of the enterprise's workforce and to identify the patterns of the workforce management policies that have taken place up to this point. The overall goal of the data mining process is to extract information from an enterprise's database set and transform it into an understandable structure for further use in the analysis, assessment and future modification of the workforce management practices. The process starts with a raw analysis step it involves database and data management issues, data pre-processing, model and inference considerations, interest metrics, complexity considerations, post-processing of discovered structures, visualization, and updating. The process continues with the data mining step that might identify multiple groups in the workforce data, which can then be used to obtain more accurate workforce prediction results.

The activities of today's world generate different a high quantity of data types. In life situations data comes from measurements, procedures and even from simulation processes. According to Sorensen and Janssens in 2003, we often come to realize that more data means less information. With the latest developments in media devices, data management, computational technologies, and automated learning techniques, the world has conquered data mining and storage and has made it very accessible. Data mining is a fresh approach, it is used to process and analyze the information hidden in data banks (Hung-Da et al., 2011).

The latest data mining techniques made available include: artificial neural networks, bayesian networks, patterns, decision trees, regression trees, and evolutionary algorithms. These techniques have turn data mining into its own field for research and development (Hung-Da et al., 2011). The following techniques use different methods to process and inspect data:

• Artificial neural networks are non-linear, predictive models that learn through training. They are powerful predictive modeling techniques easy to use and deploy. Due to their complexity, they are better employed in situations where they can be used and reused, such as reviewing transactions data.

• Decision trees are tree-shaped structures that represent decision sets. The decisions generate rules, which then are used to classify data. Decision trees are the most popular technique use to build understandable models. Management can assess, if an enterprise is using an appropriate cost-effective allocation strategy based on the assigned value of the client.

• The nearest-neighbor is a method that classifies dataset records based on similar data in historical datasets. It can be used to define a document that is of interest and ask the system to search for similar items.

Our framework uses data mining techniques to extract data pattern for the process of building models based on specified criteria from available data. Once a model is complete, it can be used in similar settings where no certain outcome is expected. For instance, an enterprise looking to select human capital can create a model of its ideal candidate based on existing data captured from human capital that were previously part of the enterprise. The model is then is used to run data queries on prospective human capital to analyze his/hers career patterns, i.e. time spent at certain divisions of an enterprise, whether lateral/vertical moves have been accomplished or whether the employee has constantly moved form position to position or remain committed to one enterprise department. Modeling will also be within reach of management to predict the number of resources required to undertake a project plan based on previously executed plans and projects of similar characteristics and requirements.

4.4. Causal Loops

The framework continues with analysis of the enterprise's interdisciplinary groups by developing causal loops addressing such areas as, "communication, complacency, contractors' environment, human factors, job satisfaction, knowledge, aging, enterprise perception and schedule pressure" (Marin et al., 2006). Several meetings and brain storm sessions are to take place to elicit the necessary information and capture the structure of the system(s). Causal loops will be validated and modified accordingly. This knowledge of the basic structure will serve as bases for the system dynamics models of workforce enterprise interaction. *Again, we would like to emphasize that* the main focus of the causal loops is to capture the structure of the system (i.e., workforce components relationships).

System Dynamics' main purpose is to analyze and map complex systems in order to search new ways to understand and interpret how problems arise within them. This methodology uses "those new ways to develop feasible policies for improvement"(Sterman, 2000; Tan et al., 2010). It provides a clear view and more information regarding any complex system.

System dynamics are used in the evaluation of diverse problem areas. These areas may include business; program/project management; human interaction and reliability; and mental workloads (Damle, 2003; Sharma et al., 2004; Sterman, 2000; Tan et al., 2010).

Sterman (2001) defined SD methodologies, as processes that facilitate effective policies for feasible improvement of enterprises. These policy-based methodologies can evaluate consequences of policy change in systems. The methodologies define "cause" and "effect" relationships between variables and consequently analyze relevant variables of any given system. As a result, those changes encountered in variables can potentially provide several outcomes across different scenarios and bring upon optimal results for previously defined goals (Damle, 2003).

To formulate the dynamic hypothesis of the problem statement, it requires the definition of the current state of problematic behaviors. An SD approach needs a causal loop diagram to provide a conceptual framework of the real world systems in terms of feedback loops. Sterman (2000) states that these "causal loop diagrams represent the relationships between variables, holistic dynamics of the model, and characterized system behavior". These diagrams are used to capture the cause and effect relationship between variables in complex systems. "To depict the type of the relationship, System Dynamics connects two variables with an arrow to define a direction of relationship, positive (+) and negative (-)" (Damle, 2003). The set of linkages represent the feedback loops in a particular system (Sterman,2001). The advantages that causal loop diagrams brings, include the mapping of the hypotheses and the causes of dynamics regarding the problems, therefore facilitating a thorough insight about the problems in high, unstable complex systems (Winch, 2001; Hung-Da et al., 2011).

An illustration of an enterprise/organization workforce management causal loop diagram is illustrated in Figure 4.2.

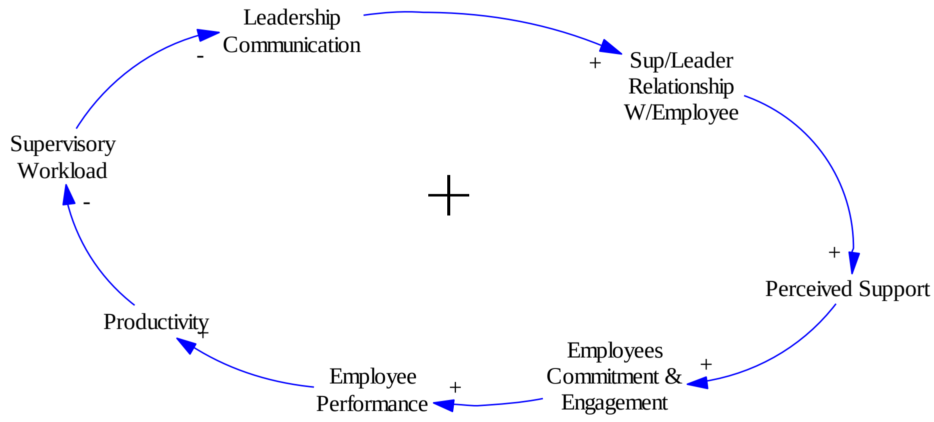


Figure 4-2. Causal loop example of workforce management activity

The diagram shows that an increase on leadership communications increases the relationship with employees leading to an increase on the perceived support by the employee; the employee is then more committed and more engaged to his tasks. Consequently, the employee performance goes up as does the productivity. Then there is a decrease in supervisory workload and a lower managerial reporting need.

4.5. Stocks and Flows (Differential Equations)

Causal models are qualitative methods, they are abstract models that describe the causal mechanisms of a given system. Now, we need to have a quantitative way to forecast resources and get a more sophisticated insight. Stocks and flows can provide this view.

For workforce modeling purposes, this framework's application of stocks and flows come into play due to the fact that enterprise workforces have :

- known strong causal relationships and their directions;
- causal relationships that can be estimated; and

- projected major changes that occur in the causal variables (i.e., major trends such as aggregate level)

Estimating model parameters or coefficients is accomplished through the use of time-series regression and cross-sectional regression. Stock and flows allow analysts to examine the effects of marketing and business activities, such as a change in prices and several key aspects thus allowing the collection of information for contingent and alternative planning.

Developing stocks and flows models calls for the selection of variables through theory and previous knowledge. The main goal is to identify relevant variables, their effect's directions, and constraints. Analysts ought to initially approach the analysis with models somewhat simple and utilize available data to project it (Allen and Fildes, 2001). Unexpectedly, according to Dawes and Corrigan in 1974 and to Dana and Dawes in 2004, simple estimates are many times enough to provide sound predictions for cross-sectional data, these authors claim that many of the latest statistical methods do not produced concrete forecasts.

Armstrong (2001) stated that through the years statisticians have developed practical procedures for evaluating how models and fit historical data, but sometimes these methods bring insufficient value to forecasters. Procedures such as measures of fit have insignificant relationship with forecast accuracy and ought to be ignored. Alternatively, subset information must be utilize to evaluate the model's predictive validity. Although questionable, statistical fit relates to forecast accuracy for cross-sectional data.

4.6. Validate Results

The validation of the initial models is accomplished through the use of historical data and by presenting the resultant models to subject matter experts, external to the enterprise, who will provide unbiased opinions and analyses.

In addition to above mentioned opinions, new rounds of interviews and discussion sessions with the different enterprise organization members may take place, here we will be able to verify the validity of the models and calibrate as needed to reflect the suggestions and recommendations obtained and reach some basic initial conclusions (i.e., trends at the aggregate level) of the state of the workforce

4.7. Agent Based Simulation (ABS)

The next step of the framework is accomplished with the use of agent based modeling techniques which require that the workforce domain behaviors be model. This part of the framework is an "interaction oriented" model; here the aim of the knowledge procured is to define the behaviors of the workforce entities and their interactions(Epstein 1996). By using ABS we can appreciate a higher resolution (i.e., disaggregation, higher level of detail) of the problem. However, we can start the modeling process by copying the validated Stock and Flow model into the initial agent-based model.

During the design of agent-based behavior-oriented simulations, modelers take agents as entities (human capital, the enterprise, etc.) that are given some behaviors and entity interaction while executing their behaviors bring up complex dynamics(Epstein, 1996). Agent based techniques handle several different and heterogeneous behaviors and domains. They are very susceptible to data driven model design disregarding averaging and aggregations. A good example of this instance is, it is possible to feed the profiles, interests and behaviors of music fanatics which were procured through lengthy data gathering into an ABS model world in order to predict an album's probability of released and reaching hit satus (Epstein, 1996, Farell 1998). Furthermore, "ABS models use a specific technique of simulating autonomous agents allowing for modeling of complex phenomena (workforce environment) and interactions" (Safarzyska et al. 2010), this framework uses this well suited modeling technique to evaluate the complex adaptive nature of any enterprise or organization (Robertson and Caldart 2008).

From the workforce environment perspective, an enterprise's agents include human capital; programs; projects; products; pieces of equipment; assets; and the enterprise itself. These agents are different, each one with its particular set of: histories, intentions, desires, properties, and complex relationships. For instance, human capital goals and expectations in terms of financial well-being and/or future employment is different when tasked with different teams; enterprises' programs depend on each other for interactions. The Agent based approach suggests that the simulation analyst focuses on individuals (workforce components) in the organization, their behavior, and interactions. "ABS model is actually a set of interacting active objects that reflect objects and relationships in the real world and thus is a natural step forward in understanding and managing the complexity of today's enterprises processes" (Anylogic.com).

The enterprises or companies of today have large amounts of relevant data that goes to waste and is seldom used. Agent based model helps this purpose in an organizational. ABS is the individual entity, then it can have real properties and characteristics of real agent. To model human capital dynamics inside the organization, this information can be directly loaded from organizational databases, giving management an "easy, precise, and up-to-date way to model, forecast, compare scenarios, and optimize strategies"(Anylogic.com).

4.8. Validate

Validating the resulting agent based model of a workforce will be accomplished by assuring operational validity. This validity refers to the adequacy and accuracy of a model in representing real world data gathered through experiments, field exercises, archives, or survey analyses of actual human capital, physical systems, and enterprise units. External validity refers to adequacy, which means that a model passes a testing process against evidence from the real world. The highly abstract nature of agent based model makes validation of these models a very difficult one.

Internal validity allows analysts to draw causal links, therefore, such a model will yield sound and replicable results. It is referred to as conclusive adequacy, which means that a model (isolated in a computer) properly produces effects as predicted by the design (Liu, 2011). Internal validity can also be reached by having a concord about the model design from the members of a workforce or the different enterprise units (Anylogic.com). “As long as the behavior rules and environmental settings of a model make sense, this type model can be seen as being internally valid” (Liu, 2011).

4.9. Analysis and Policy Development

In a similar fashion as was done for the initial assessment of the workforce state, the proposed strategic procedures will be analyzed with the only difference being that the data may come from expert opinions and estimates and also using sensitivity analysis and applying optimization techniques. The next step in the framework will be to communicate the workforce plan and implement its strategies. Then valuate the current strategies compared to proposed changes, thus recognize how new practices measure up. While some components impede successful implementation of new and complex procedures, our goal is to foresee complex interactions that result from changes to the workforce enterprise system. At this stage of the framework decisions take place, these decisions account for the components interactions derived from enterprises methods (Cintrón, 2013).

After complimentary review and study of results, we will see a resultant proposed “to-be” workforce system. The proposed framework will provide a model that understands the complex behaviors of a newly designed workforce system. The analysis undertaken here will be based on complex systems that are controlled by system’s procedures influences and time delays that occur during procedure execution. Since so many different parameters can become particularly important to the stability of systems they become major determinants when they affect the feedbacks that procedures have on each other while acting together in a complex workforce system methods (Cintrón, 2013). These complex behaviors can therefore impact workforce behavior from change implementation over time. This phase of our framework analyzes the behavior and soundness by modeling. With an analysis of feedbacks, time delays, and stability of a new system, the framework provides details on how the workforce enterprise will behave from procedural changes. Complex behavior modeling lets discover effects on workforce system and how changes to inputs and procedures may be utilized to assess the behavior of entire workforce systems methods (Cintrón, 2013)..

At the end, workforce management officials of any enterprise should monitor, evaluate and revise the state of the workforce after plan implementation, then evaluate results, and make adjustments accordingly. Finally, management needs to take on new organizational issues that influence workforce climate and model accordingly (Hung-Da et al., 2011).

CHAPTER 5. CASE STUDY OF NASA KSC WORKFORCE

5.1. Introduction to NASA KSC Study

This case study occurred in 2005, there were many factors that influenced the NASA Kennedy Space Center workforce in 2005. These factors ranged from the global and local economic pressures, the end of the Shuttle Program, "the expected return to flight and the vision for continued space exploration which calls for the development of a new launch vehicle" that is schedule to launch later in 2018. Additionally, external factors exist as well, such as the area's cost of living, the availability of skilled employee prospects, and the current unemployment numbers affect the entire workforce climate (Marin et al., 2006). "In order to manage the human capital in a manner consistent with safety and mission success, and to strategically position NASA KSC to execute its future mission, it is necessary to understand how all of these different influencing factors work together to produce an overall workforce climate". Our case study seeks to find a solution that matches the KSC workforce to the budget assigned by the US Government without losing experienced and high productive human components (Zhu et al. 2007).

For the NASA KSC workforce enterprise, planning and productivity were an important concern. With the effects of re-organizations in the earlier 2000's, the emphasis on "do more with less," increasing changes and additions of new launch programs, the higher pace of technological change, uncertainties in projects and the complex and conflictive economic forces, the development of effective workforce planning strategies is becoming a very difficult challenge.

Developing planning models, organizational learning, and experimentation will nurture this ability. This research proposed to build a decision-making system based on multiple models and system dynamics to provide new ways to model and simulate the NASA KSC workforce enterprise and promote organizational planning in order to achieve effective workforce planning strategies to accomplish the required launch rates and mission success.

This chapter utilizes the framework to develop a solution for the case study of NASA KSC in 2005 where the main objective was to avoid layoffs of the "experienced" NASA Workforce because of budget constraints prompted by the end of the shuttle program.

5.1.1. Approach Using our Framework (Step by Step)

Our approach sought to provide NASA KSC with means to avoid lower performance and productivity due to layoffs of the "experienced" NASA Workforce because of budget changes.

In order to achieve this goal, the following tasks are to be accomplished (Marin et al., 2006):

- Analyze the current situation at NASA KSC
- Collect and analyze workforce information
- Develop causal loops in conjunction with interdisciplinary groups as depicted in Figure 5-1. There should be several group sessions to develop a set of causal loops addressing such areas as: aging chain, communication, complacency, contractors' work settings, human factors, job satisfaction, knowledge, morale, motivation, employee perception of NASA KSC, and schedule deadlines.
- Take the causal loops results and discuss them with subject matter experts external to NASA KSC or government influence, in order to obtain straight and unbiased evaluations, opinions and analyses. The initial goal is to at a minimum be able to validate the causal loops obtained and arrive at some initial basic conclusions.

- Design an validate a stock and flows model of the aggregation of the workforce dynamics at NASA KSC.
- Design an agent-based model of the workforce dynamics using disaggregation as the basis for development.

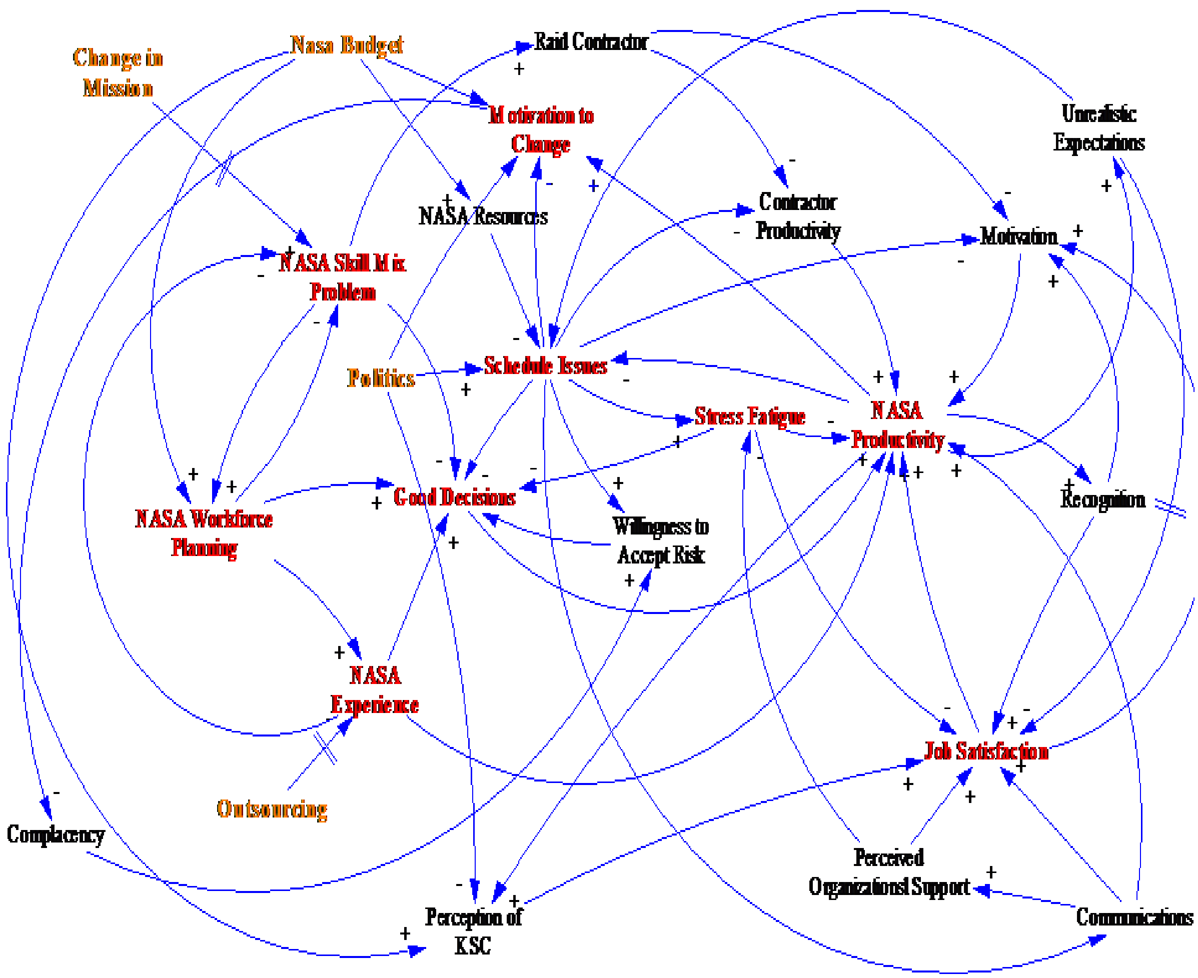


Figure 5-1. Aggregate causal loop of NASA KSC Interdisciplinary Groups Workforce Factor Brainstorming Sessions (2004 – 2005)

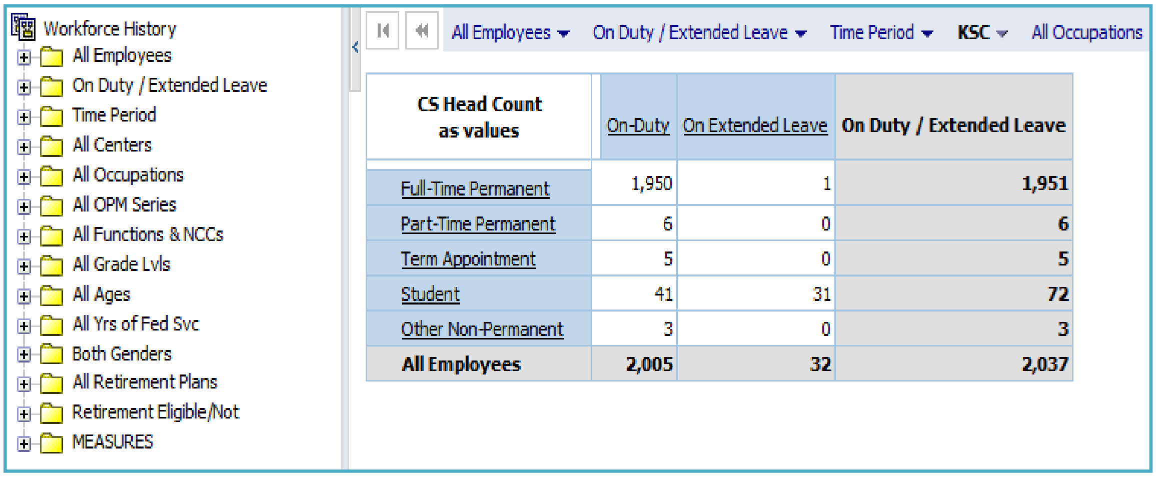
5.1.2. Current Situation of NASA KSC (2005)

In 2005, as NASA KSC prepared for the shuttle era to end in 2010, management needed ways to prepare to manage the "human capital in a manner consistent with safety and mission success, and to strategically position NASA KSC to execute its future mission. It was then necessary to understand how all of the external and internal factors that influenced the enterprise work together to produce an overall workforce climate" (Zhu et al. 2007).. There was a need to: find a solution to match the workforce to the budget assigned by the US Government without losing experienced and high productive employees, taking into account that NASA KSC vision for continued space exploration called for the end of the shuttle era and for the development of a new launch vehicle expected to launch later in 2018.

5.1.3. Data Mining

Workforce information for NASA employees is made available by the" workforce strategy division in the office of human capital management"; it provides updated workforce information every two weeks. The database, as depicted in Figure 5-2, contains multiple dimensions of the enterprise workforce (wicn.nssc.nasa.gov/wicn_cubes.html?).

This data repository contains information related to all NASA " locations, occupations, grades, salaries, and demographics (NASA cubes, 2005). This information comes from the personnel file system", it can be gathered, by NASA center, on the employees distribution, distribution of occupational groups, headcount of all employees on the NASA rolls, historical trend in headcount of all employees by year, and age distribution of full-time permanent employees since 1993 (wicn.nssc.nasa.gov/wicn_cubes.html?).



CS Head Count as values	On-Duty	On Extended Leave	On Duty / Extended Leave
Full-Time Permanent	1,950	1	1,951
Part-Time Permanent	6	0	6
Term Appointment	5	0	5
Student	41	31	72
Other Non-Permanent	3	0	3
All Employees	2,005	32	2,037

Figure 5-2. Aggregate Workforce Information Cubes For NASA

The NASA cubes also provide detailed information of workforce distribution and assignments, throughout the different locations on all programs, missions, and projects. The information covers not only fulltime employees (FTE), but also all employee types. This information relates to all missions and all centers, it provides inside on distribution by mission, deployment measures by mission and center, retirement eligibility by mission and center, burn rate (employee cost) by pay period by mission and center.

Additionally, this data repository provides forecast of future retirements by job, by center, based on past practices and experiences and on the persons now eligible or becoming eligible to retire. This type of workforce information is calculated using historical losses and the current NASA KSC workforce profile. NASA losses forecast are provided on a 2 year average by center and by occupation group. The attrition forecast numbers is also provided for 5 year periods and the average number of years any employee has worked past his/hers initial optional retirement eligibility date. The repository also details workforce personnel transaction/decision since 1993 in the form of the number of total: hires, losses, buyouts and promotions.

NASA has different types of employees that have been categorized in the following manner as depicted in Table 5-1. NASA employees can be civilian, military personnel, presidential appointees or recent college graduates. They can be employed full time, part time, for a certain term (period of time), temporary, under a cooperative education program, under an internship program, and under an international engineering program.

Table 5-1. NASA Employee Types

NASA Employee Types				
Full Time	**Part Time**	**Term Appointment**	**Students**	**Other non-permannet**
Full Time Permanent	Part Time Permanent	Term Employee	CO-OP	WAE Expert/Consultant
Full Time Permanent Military	Part Time Permanent LWOP	Term Employee LWOP	CO-OP - LWOP	Temporary
Full Time Permanent LWOP		Term Employee Military	Intern (IEP)	Special Handicap Appointment
Presidential Management Fellow			Intern (IEP) - LWOP	Summer Aid (IEP)
Recenet Graduates			Intern NTE - (IEP)	

For this research purpose, our effort was directed at obtaining meaningful data related to the different employees age groups. This detailed data process produced information about gender per age group, number of employees per age group, the hiring percentage per age group and most importantly the probability that each age group employee has of leaving the enterprise. These results are depicted in table 5-2. Here we found that the employees age ranges from 23 years old to 70 years old. The average employee age is 46.5 years old. Further analyzing the data, we found that for the number of employees per age group we have, as shown in figure 5-3: the maximum number of employees in any age group is of 107 which belongs to the 47 year old group; the minimum number of employees in any age group is of 3 which belongs to the 67 year old group; the average number of employees per age group is of 42.75.

Table 5-2. NASA KSC Employee Information By Age Group

AGE	Initial Number	HIRE %	Probability of leaving the system %
23	34	9.05%	31
24	33	7.12%	28.1
25	30	5.01%	8.3
26	26	3.08%	24.1
27	28	2.46%	22.2
28	22	3.08%	11.1
29	13	2.64%	13.8
30	16	3.60%	3.7
31	16	3.34%	6.4
32	11	2.20%	1.8
33	35	1.93%	7.6
34	32	1.76%	1.8
35	24	2.28%	3.5
36	38	2.99%	3.4
37	52	2.90%	2.5
38	52	3.51%	1.2
39	81	3.25%	2.4
40	94	3.78%	2.8
41	105	4.22%	4.8
42	107	3.69%	1.1
43	97	3.25%	1.5
44	90	2.90%	2.6
45	99	2.02%	0.5
46	89	2.37%	1.7
47	75	2.55%	3.3
48	67	1.85%	1.8
49	63	1.32%	2.2
50	60	2.28%	2.7
51	63	1.14%	0.7
52	54	1.41%	4.2
53	55	1.05%	1.7
54	34	0.79%	2.3
55	52	0.79%	10
56	46	1.05%	8.8
57	56	0.88%	3
58	37	0.88%	2.8
59	43	0.44%	10.8
60	33	0.44%	15.4
61	23	0.09%	13
62	12	0.26%	27.1
63	16	0.00%	8.6
64	14	0.09%	17.3
65	8	0.00%	29
66	4	0.00%	25
67	3	0.09%	0.25
68	0	0.09%	0.25
69	3	0.00%	0.25
70	7	0.09%	0.25

Figure 5-3. Number of Employees per Age Group

Regarding information about the number of employees that are going to be hired at NASA KSC, as seen in figure 5-4, we found that the average probability of hiring per age group is of 2.08% represented in the 24year old age group; the highest probability of hiring belongs to the 34 year old group with a 9.05%; the lowest probability of hiring belongs to the 64, 67, 68 and 70 year old groups with a 0.09%.

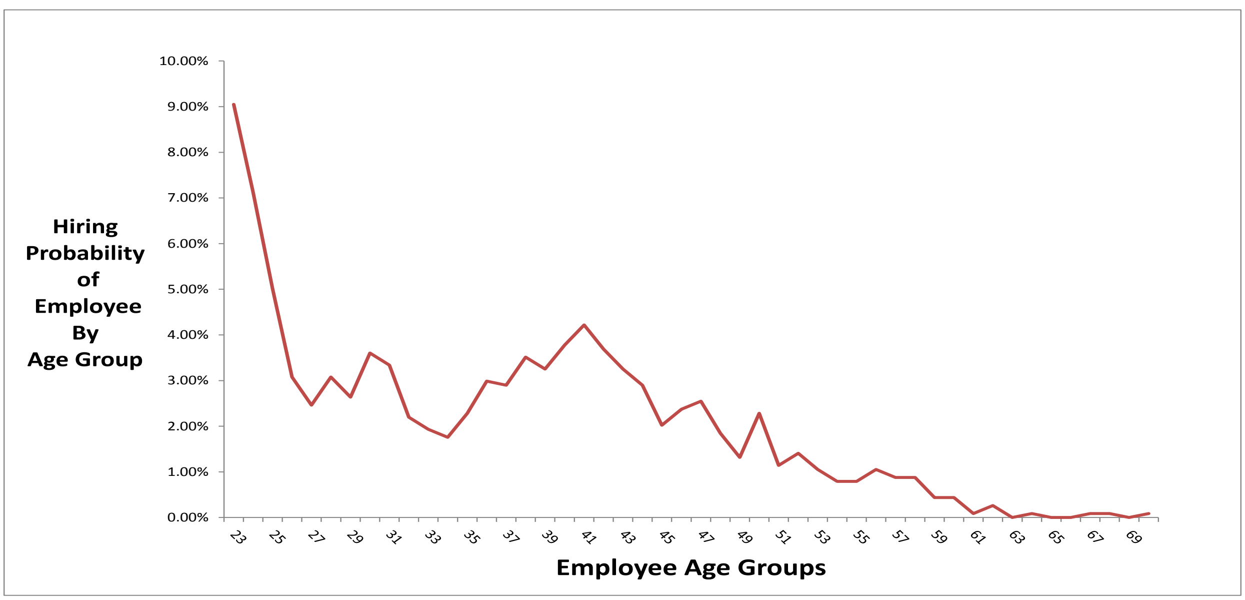


Figure 5-4. Probability of Hiring Employees by Age Group

In terms of information about the number of employees that are going to be leaving the enterprise at NASA KSC, as seen in figure 5-5, we found that on the average, the probability of leaving per age group is of 7.88% represented in the 33 year old age group; the highest probability of leaving belongs to the 23 year old group with a 31%; the lowest probability of leaving belongs to the 45 year olds and to the 66 to 70 year old group who had a 0.55% and 0.25% respectively.

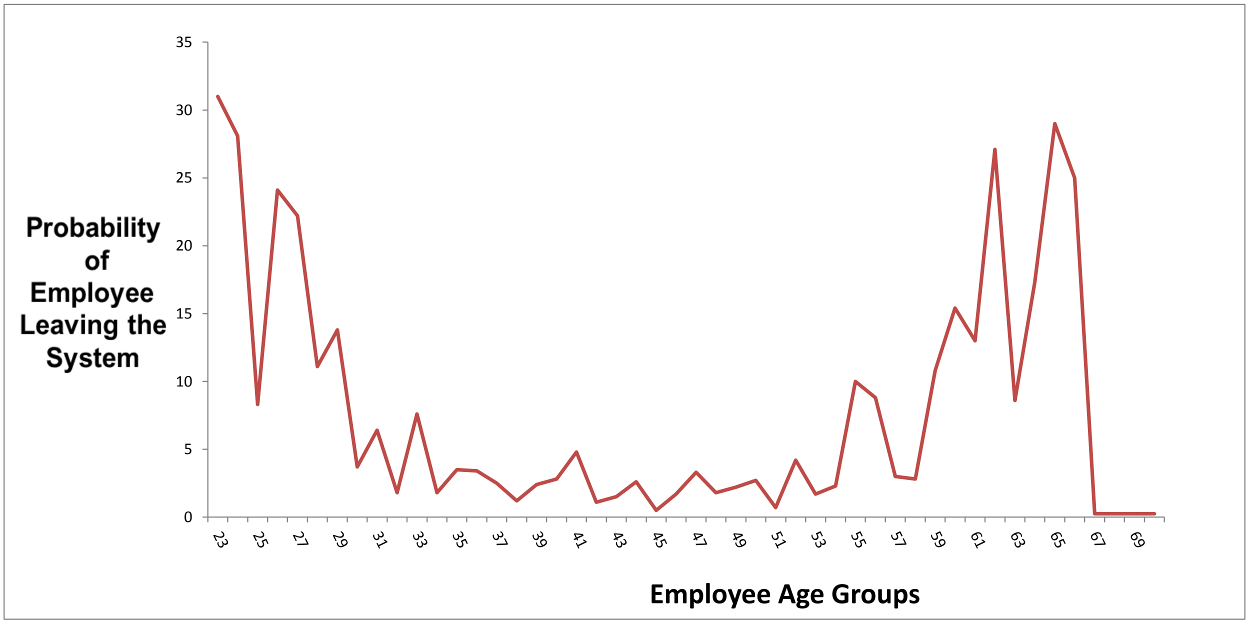


Figure 5-5. Probability of Employees by Age Group of Leaving the System

5.1.4. Causal Loops

Numerous brainstorming sessions of interdisciplinary groups (figure 5-6) were held to discuss and address NASA KSC workforce factors. These groups were composed by professionals from the system dynamics field; the economics, finance and management field; form the industrial psychology field in addition to NASA KSC enterprise environment groups. These sessions, which led to the development of a "set of causal loops, addressed the areas of: aging chain, communication, complacency, contractors' environment, human factors, job satisfaction, knowledge, morale, motivation, perception of NASA KSC and schedule pressure" (Marin et al., 2006).

The above mentioned areas of concern have a number of variables that were considered in the development of the causal loops. (See appendix for all arrears of concern and their variables)

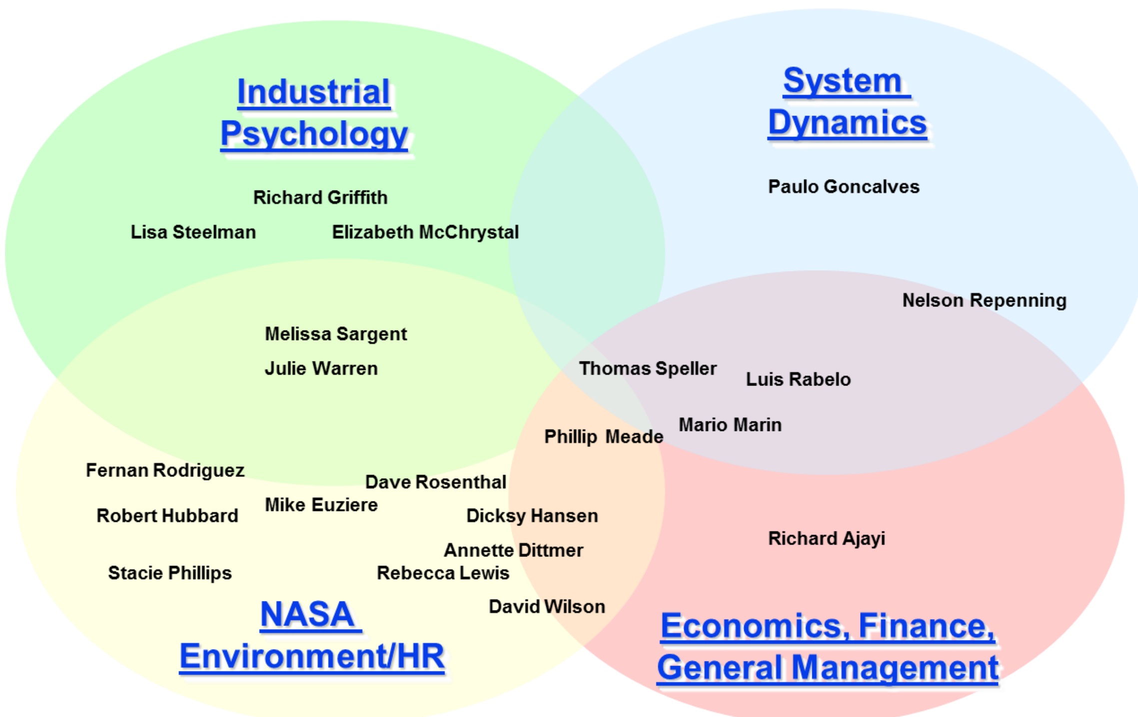


Figure 5-6. NASA KSC Interdisciplinary Groups (2004 – 2005)

For instance, the causal loop described in Figure 5-7, determines the result of an aging workforce within the space center. The rate of recruiting efforts, hiring freezes and declinations in job offers effects the number of newly hired employees. New hires along with workforce planning help build a strong pipeline of trained and talented employees, which come from a predetermined hiring order of either raiding area contractors or sorting through the current pool of applicants. This pool of applicants, new hires, hiring from other centers, recruiting, hiring freezes, and declinations all affect the level of diversity within the NASA KSC leading to diversity of thought. From this thought process good policies and sound decisions can be undertaken leading to greater levels of productivity.

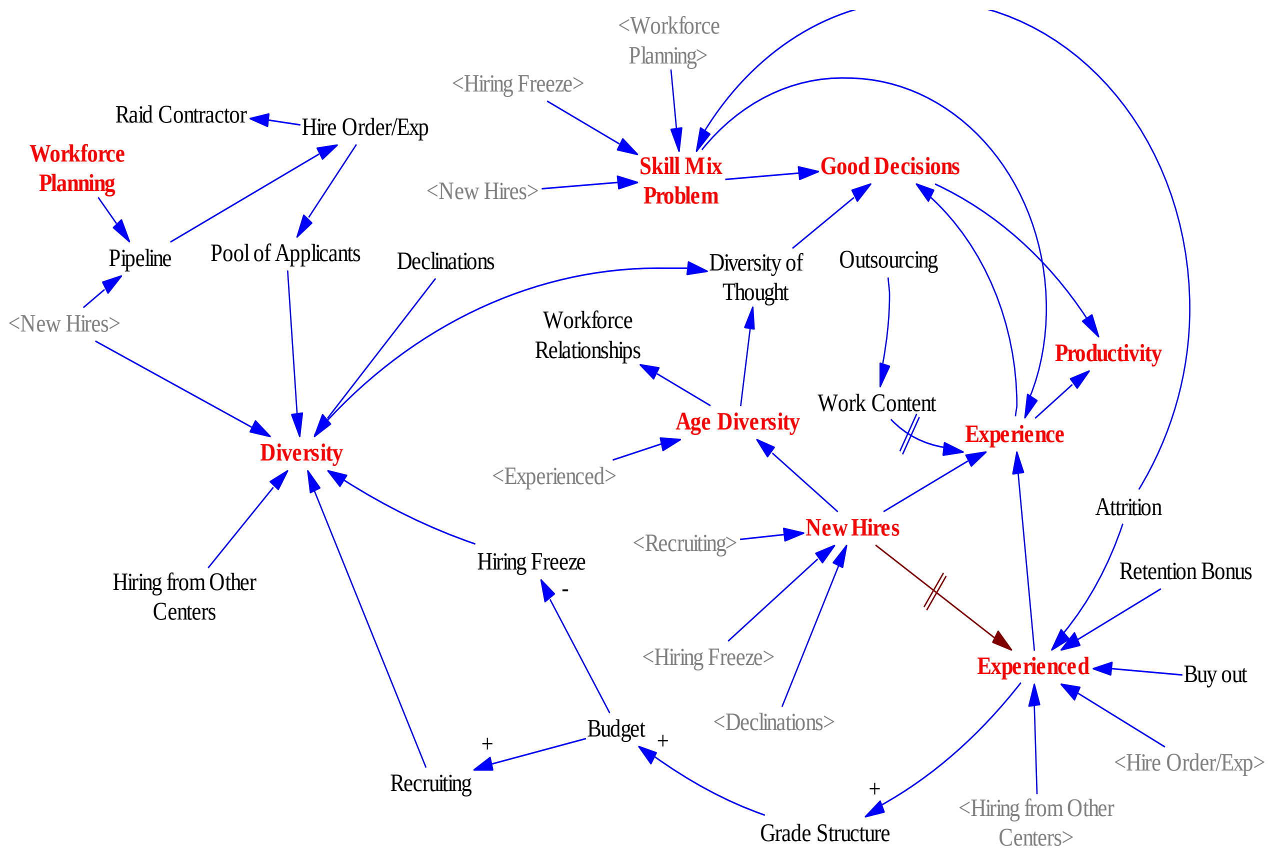


Figure 5-7. Aging Chain Causal Loop

Various iterations took placed to analyze the workforce factors and their interactions. Sessions addressed the issues that range from the change in mission and productivity to employee performance, job satisfaction and NASA KSC hiring practices. An aggregate loop containing all the factors mentioned above, was the result (Figure 5-8). It showed how NASA KSC productivity was influenced primarily by managerial decisions which were a result of existing workforce planning strategies; these strategies were the result of resource planning done according to budget implications that drive the future needs of the enterprise. This aggregate loop also shows workforce environment factors such as by leadership communication, employee satisfaction and perception of NASA KSC that the employee had. Additionally, the future change in mission carried additional skill mix requirements to be met.

Finally a rigorous validation process took place where different sessions were performed by the interdisciplinary groups who had to identify the areas required to solve the problem statement as outlined in chapter 1. Additionally, Massachusetts Institute of Technology system dynamics experts performed a thorough analysis of the developed models and provided their opinions regarding the validity of the developed models.

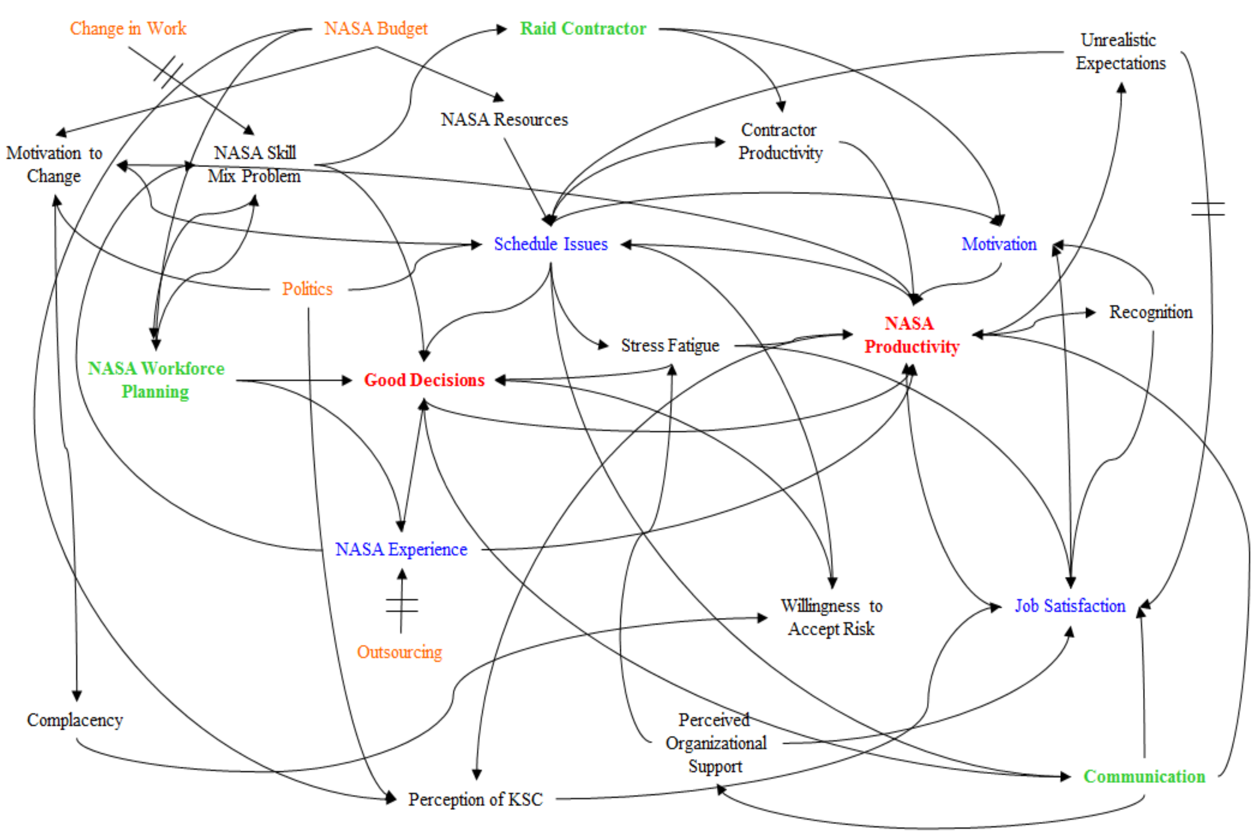


Figure 5-8 Causal Aggregate Loop Model

5.1.5. Stocks and Flows (Differential Equations)

The resultant system dynamics model demonstrated the aging of the NASA KSC workforce. This model captures the NASA KSC human capital pool different behavior patterns. The model has 63 differential equations (Figure 5-9) that resulted from the interpretation and implementation of the aggregate causal loop developed to represent the workforce environment at NASAKSC (Marin et al. 2006). The following are examples of those differential equations generated by the SD model, here we see the hiring differential equations for KSC employee group ages 23 and 24.

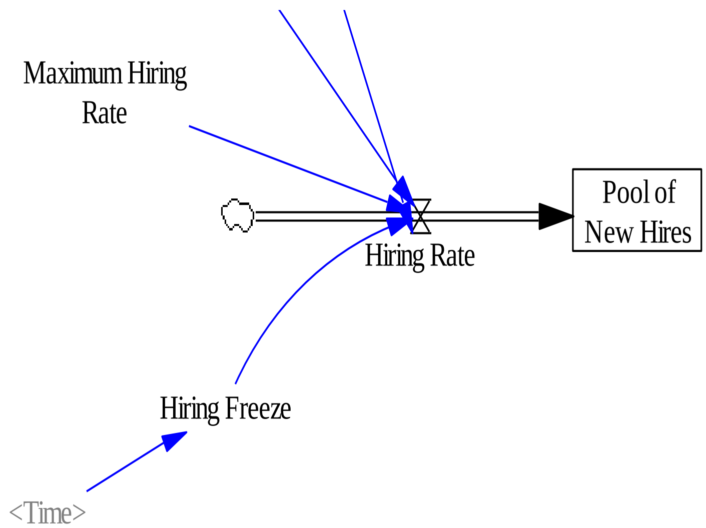
$$A23 = \int_{t=0}^{t=i} dt + 34$$

$$\frac{dA23}{dt} = \text{(Hire23-Age23-Attrit23)+34}$$

$$A24 = \int_{t=0}^{t=i} dt + 33$$

$$\frac{dA24}{dt} = \text{(Age23+Hire24-Age23-Attrit23)+33}$$

Anylogic is the simulator of choice at the core of the workforce enterprise simulation. The model allows managers to interactively set up and graphically assess the hiring rate parameters, resource requirements all according to wants, needs and allocated budgets.



$$Pool\ of\ New\ Hires = \int_{t=0}^{t=i} dt$$

$$\frac{dPool\ of\ \ New\ Hires}{dt} =$$

(Hiring rate- Hire23-Hire24-Hire25-Hire26- Hire27-Hire28-Hire29-Hire30-Hire31-Hire32-Hire33-Hire34-Hire35-Hire36-Hire37-Hire38-Hire39-Hire40-Hire41-Hire42-Hire43-Hire44-Hire45-Hire46-Hire47 -Hire48-Hire49-Hire50-Hire51-Hire52-Hire53-Hire54-Hire55-Hire56-Hire57-Hire58-Hire59-Hire60-Hire61-Hire62-Hire63-Hire64-Hire65-Hire66-Hire67-Hire68-Hire69-Hire70-Hire53-Hire54-Hire55-Hire56-Hire57-Hire58-Hire59-Hire60-Hire61-Hire62-Hire63-Hire64-Hire65-Hire66-Hire67-Hire68-Hire69-Hire70)

Figure 5-9. Example of a workforce model differential equation .

The following table has all the differential equations of the model.

Table 5-3. Differential equations of the SD hiring model

A23= INTEG ((+Hire23 - Age23-Attrit23),34)
A24= INTEG ((Age23+Hire24-Age24-Attrit24),33)
A25= INTEG ((Age24+Hire25-Age25-Attrit25),30)
A26= INTEG ((Age25+Hire26-Age26-Attrit26),26)
A27= INTEG ((Age26-Age27+Hire27-Attrit27),28)
A28= INTEG ((Age27+Hire28- Age28 -Attrit28),22)
A29= INTEG ((Age28+Hire29-Age29-Attrit29),13)
A30= INTEG ((Age29+Hire30-Age30-Attrit30),16)
A31= INTEG ((Age30+Hire31-Age31-Attrit31),16)
A32= INTEG ((Age31+Hire32-Age32-Attrit32),11)
A33= INTEG ((Age32+Hire33-Age33-Attrit33),35)
A34= INTEG ((Age33+Hire34-Age34-Attrit34),32)
A35= INTEG ((Age34-Age35+Hire35-Attrit35),24)
A36= INTEG ((Age35+Hire36- Age36 -Attrit36),38)
A37= INTEG ((Age36+Hire37-Age37-Attrit37),52)
A38= INTEG ((Age37+Hire38-Age38-Attrit38),52)
A39= INTEG ((Age38+Hire39-Age39-Attrit39),81)
A40= INTEG ((Age39+Hire40-Age40-Attrit40),94)
A41= INTEG ((+Hire41-Age41-Attrit41+Age40),105)
A42= INTEG ((Age41+Hire42-Age42-Attrit42),107)
A43= INTEG ((Age42+Hire43-Age43-Attrit43),97)
A44= INTEG ((Age43+Hire44-Age44-Attrit44),90)
A45= INTEG ((Age44-Age45+Hire45-Attrit45),99)
A46= INTEG ((Age45+Hire46 - Age46 -Attrit46),89)
A47= INTEG ((Age46+Hire47-Age47-Attrit47),75)
A48= INTEG ((Age47+Hire48-Age48-Attrit48),67)
A49= INTEG ((Age48+Hire49-Age49-Attrit49),63)
A50= INTEG ((Age49+Hire50-Age50-Attrit50),60)
A51= INTEG ((+Hire51-Age51-Attrit51+Age50),63)
A52= INTEG ((Age51+Hire52-Age52-Attrit52),54)
A53= INTEG ((Age52+Hire53-Age53-Attrit53),55)
A54= INTEG ((Age53+Hire54-Age54-Attrit54),34)
A55= INTEG ((Age54-Age55+Hire55-Attrit55),52)
A56= INTEG ((Age55+Hire56 - Age56 -Attrit56),46)
A57= INTEG ((Age56+Hire57-Age57-Attrit57),56)
A58= INTEG ((Age57+Hire58-Age58-Attrit58),37)
A59= INTEG ((Age58+Hire59-Age59-Attrit59),43)
A60= INTEG ((Age59+Hire60-Age60-Attrit60),33)
A61= INTEG ((Age60+Hire61-Age61-Attrit61),23)
A62= INTEG ((Age61+Hire62-Age62-Attrit62),12)
A63= INTEG ((Age62+Hire63-Age63-Attrit63),16)
A64= INTEG ((Age63+Hire64-Age64-Attrit64),14)
A65= INTEG ((Age64-Age65+Hire65-Attrit65),8)
A66= INTEG ((Age65+Hire66 - Age66 -Attrit66),4)
A67= INTEG ((Age66+Hire67-Age67-Attrit67) ,3)
A68= INTEG ((Age67+Hire68-Age68-Attrit68) ,0)
A69= INTEG ((Age68+Hire69-Age69-Attrit69),3)
A70= INTEG ((Age69+Hire70-Age70-Attrit70),7)

5.1.6. Validate results

The validation of the initial models is accomplished through the use of historical data and by presenting the resultant models to subject matter experts, external to the enterprise, who provided unbiased opinions and analyses.

In addition to above mentioned opinions, new rounds of interviews and discussion sessions with the different enterprise organization members took place, here we were able to verify the validity of the models and calibrate as needed to reflect the suggestions and recommendations obtained and reached some basic initial conclusions (i.e., trends at the aggregate level) of the state of the workforce.

Initial validation of the causal loops developed is accomplished by obtaining analysis and opinions of the Massachusetts Institute of Technology system dynamics experts. Stocks and flows model were developed capturing all the characteristics if the interactions and dynamics of the NASA KSC workforce environment.

According to the current conditions (2005) of the NASA KSC workforce environment, the results show the following graphs which corroborate the state of the aging workforce at present and projected up for the next 20 years. The following graphs of 5 different workforce age groups show:

- From 23 to 30 (Figure 5-10), it initially stands at 200 and steadily declines over the next 8 years (up to 2013) when it hits a low number of under 100 to then increase steadily for the following 12 years(up to 2025) where it reaches the 150 number of employees for this group.

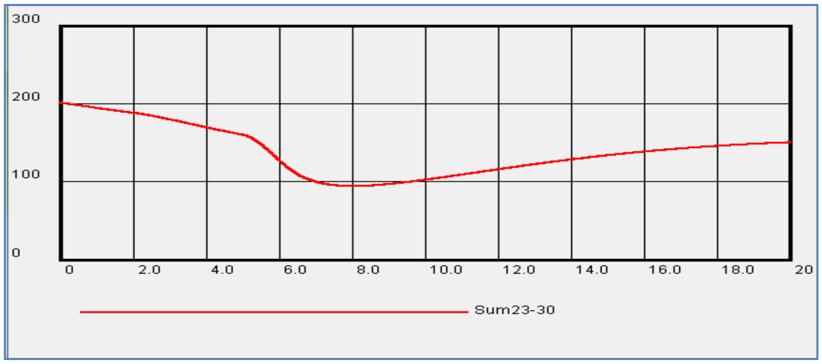


Figure 5-10. Age group 20-30

- From 31 to 40(Figure 5-11), it initially stands at 425 and declines over the next 8 years (up to 2013) when it hits a low number of 275 to then increase for the following 12 years (up to 2025) where it reaches the 325 number of employees for this group.

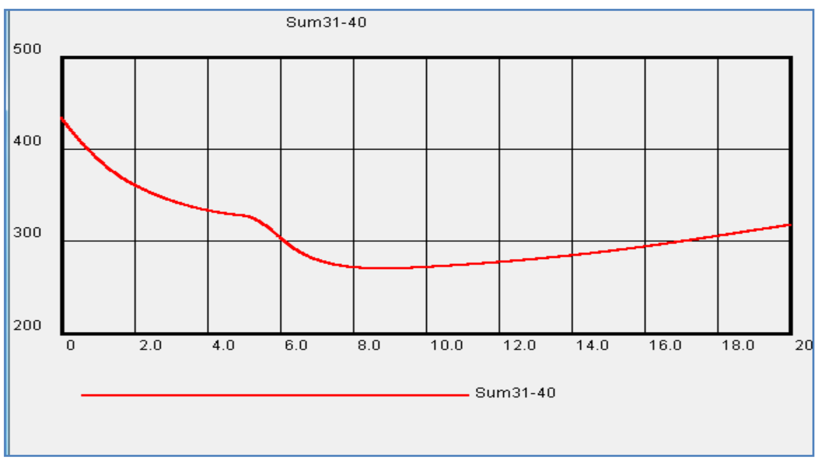


Figure 5-11. Age group 31-40

- From 41 to 50 (Figure 5-12), it initially stands at 850 and increases for a 2 and a half years up to 920 then declines over the next 10years (up to 2015) when it hits a low number of 275 to then increase for the following 12.5 years (up to 2021) where it reaches the 540 number of employees then reverses its course and climbs up to 575 in 2025.

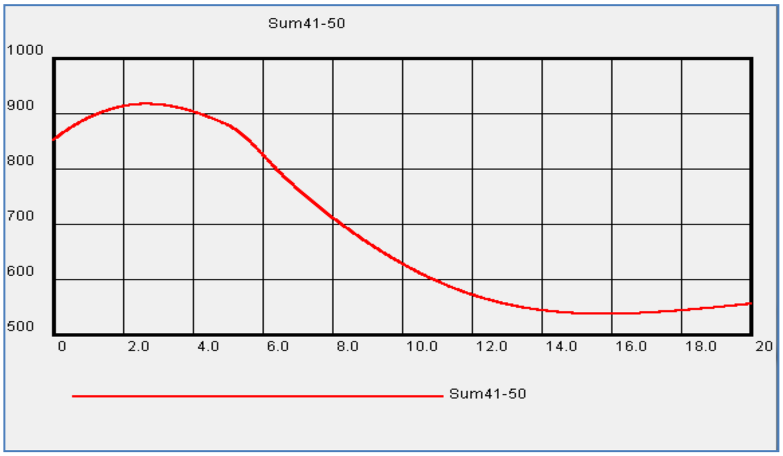


Figure 5-12. Age group 41-50

- From 51-60(Figure 5-13), it initially stands at 475 and increases steadily for the next 12 years, peaking at 750, then declines over the next 8 years (up to 2025) when it hits a low number of 530.

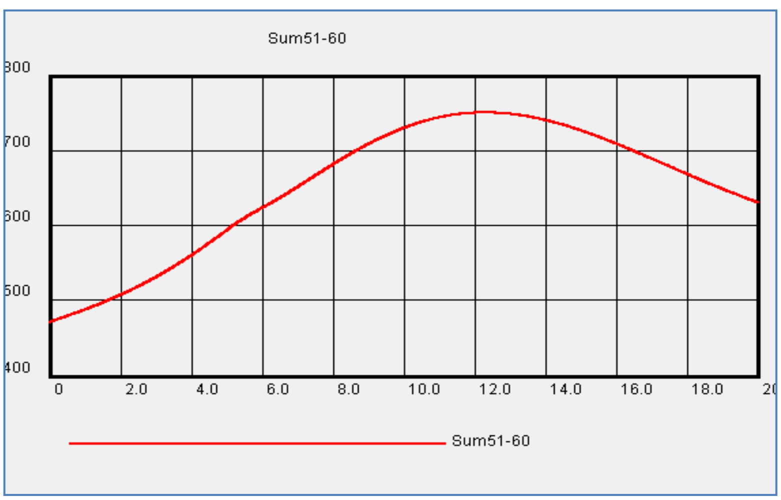


Figure 5-13. Age group 51-60

- From 61-70(Figure 5-14), it initially stands at 90 and increases steadily for the next 20 years to reach a maximum of 245 in the years 2025.

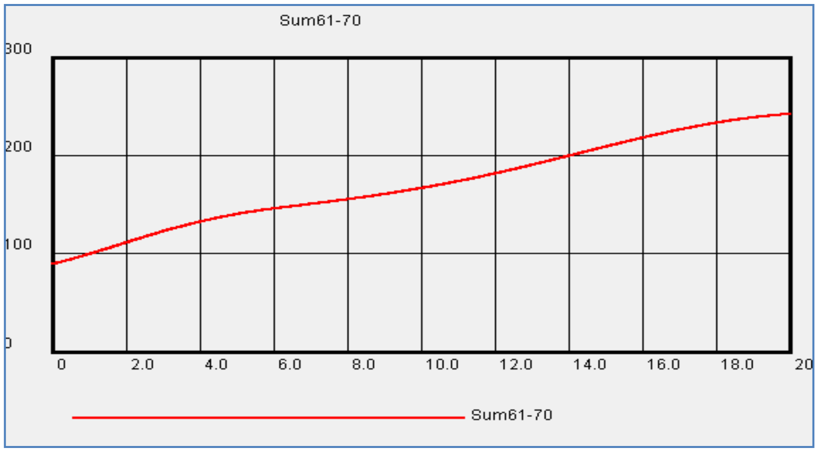


Figure 5-14. Age group 61-70

The following graph (Figure 5-15) depicts the total workforce number of employees that are going to be needed (2005 estimates and workforce conditions) over the next 20 years. This graph shows

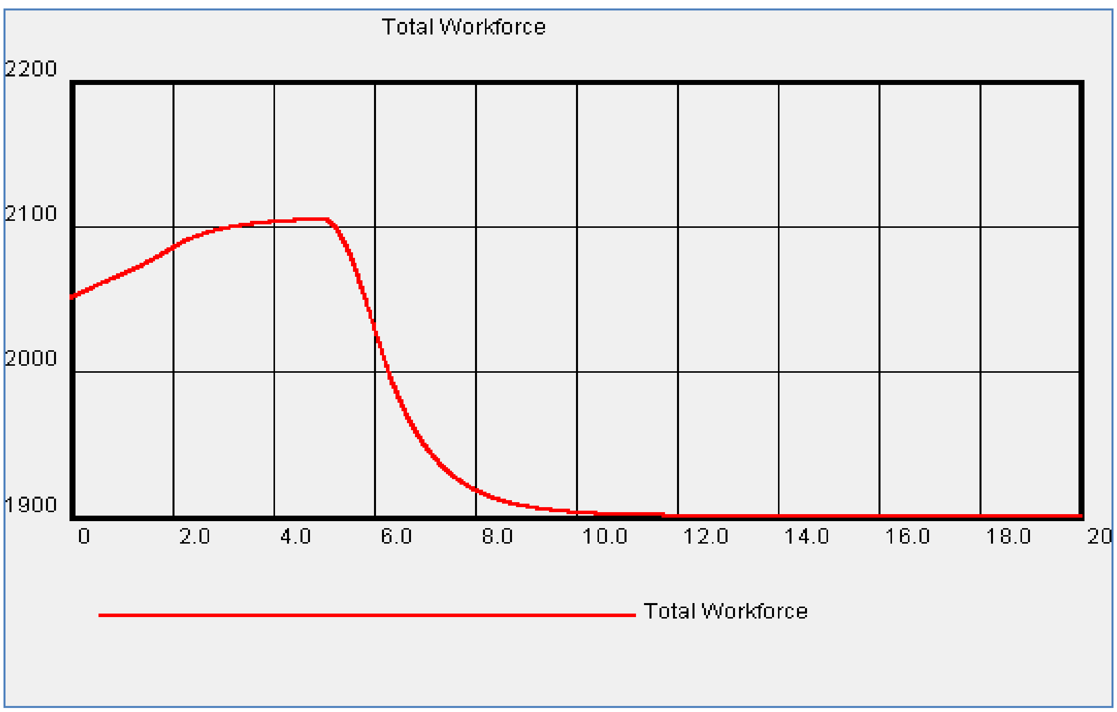


Figure 5-15. KSC total workforce

A sudden increase in the number of hires over the years 2005 and 2009 and a sudden and quick workforce reduction in 2009 that lasted until approximately 2012. After this sudden change, the reduction eased a little and reached a steady 1900 employee headcount for the rest of the simulated period up to 2025.

The above mentioned projected reduction made management aware of the fact that there changes to be made in hiring policies and strategies in order to continue to deliver quality production for the current and future projected demands of the center at NASA KSC. Most importantly, the realization of that fact that many employees needed to be let go was made very clear by the representation of the following Figure 5-16, which shows is a clear gap between total workforce and the OMB requirements (Office of management and Budget).

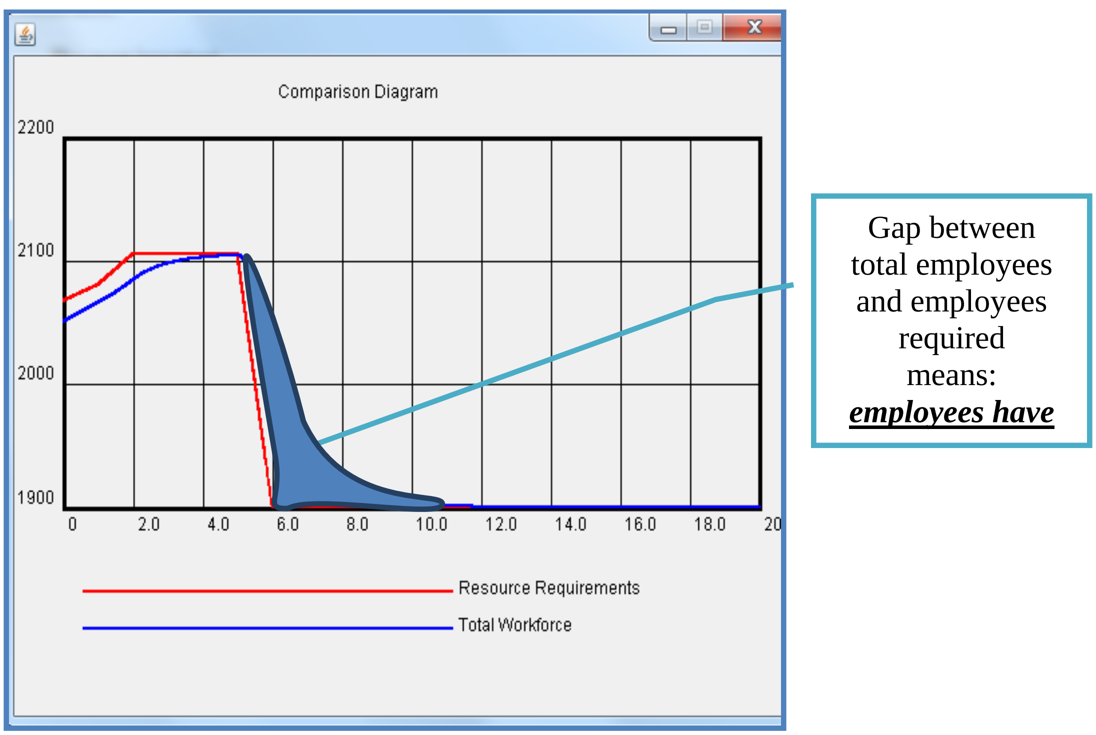


Figure 5-16. KSC Total workforce vs Resource Requirements

The projections for the center showed the number to be at a little more than 2100 employees by the year 2010, a number that would be matched by the total resources required. It was then that the numbers for OMB requirements would be taking a sharp drop (form 2100 in 2010 – to 1900 in 2011), while the numbers for total workforce would decline at a much slower pace (from 2100 in 2010 to 1900 in 2017) .

5.1.7. Agent Based Model

During our design of agent-based behavior-oriented simulations, we designate agents as entities (NASA employee and NASA KSC) that have certain characteristics and behaviors, and have certain interactions among them. The modeling system selected is AnyLogic™, a simulation software developed by XJ Technologies (http://www.xjtek.com/). "AnyLogic™ was selected, among other reasons, because it is based on Java, an object-oriented programming (OOP) language which is desirable as it allows reusability, extensibility, and maintainability" (Marin et al., 2006). This simulation platform implements agents, system dynamics, continuous, and discrete-event systems.

5.1.7.1. Hybrid Behavior in AnyLogic

AnyLogic follows an object oriented approach. Statecharts which are associated with objects (called active objects). It indicates the state space of the object and the events that cause it to take transitions from a state to another. It can also describe actions that result from state change. Figure 5-17 is a statechart of an active object in AnyLogic. The initial state is where the object is at when it starts to exist. Boxes are the states. Arrows represent the transitions. The transitions are fired upon the occurrence of events. Java code is used to define the reactions to the occurrence of the events in the states and transitions.

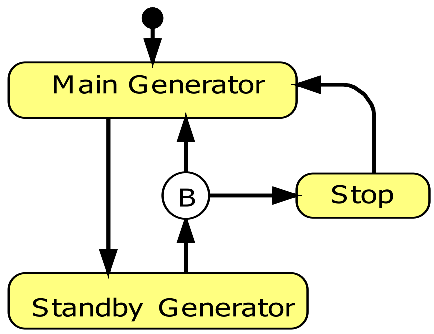


Figure 5-17. Statechart in AnyLogic

A system would initially be using the main generator. The transition from main generator to a standby generator would fire if a message arrives at the object that the main generator is down. The transition from Standby to B (which is a branch) can be timed for two as many hours as needed. If a signal that the main generator is fixed arrives at the end of the time needed then the transition will be to the main generator state, else the transition is to the stop state to stop the system.

The statechart can react to events only. Events are discrete. The models are basically discrete models but continuous behavior can be incorporated. To incorporate continuous behavior in a discrete model, AnyLogic defines variables using algebraic-differential equations and ling the values of these variables to the objects in the model. Conditions are defined for these variables such that when a variable reaches a certain value an event can be created. Such an event is called a *change event*. The change events are sensed at the statechart and they can enable transitions just like the other discrete events and they take zero time as well to occur. For instance, if the customer order rate, which is defined by a continuously changing variable exceeds 10000 units per week then move from no overtime state to overtime state. However, this transition may not be taken unless the management indicates that overtime is allowed. Allowing or not allowing overtime can be a guarding condition over the transition.

Further, the states can have mathematical equations defined for some of them. When the state is executed the equations are solved to cause some continuous reaction in the system (change the values of some variables, which may cause change events). Or the states can be set to cause other discrete events to be scheduled. When continuous and discrete behaviors are defined in the same statechart in AnyLogic, it is called hybrid statechart. It is through the use of variables and hybrid statechart that AnyLogic provides hybrid system behavior.

The mathematical forms used in AnyLogic are all functions in time. This is what makes them used for continuous time behavior. Three forms are available to be used with variables or in the states or maybe associated with the transitions. The forms are listed below, where f, g, h are arbitrary functions in variables x and y. The symbol $find(x)$ is a method that solves a set of simultaneous algebraic equations:

$$\begin{array}{ll} \text{Differential Equations}: & d(x)/dt = f(x,y,t) \\ \text{Algebraic equations}: & g(x,y,t) = 0,\ find(x) \\ \text{Formulas}: & h(x,y,t) \end{array}$$

Thus the hybrid statechart is the link between the discrete engine in and the hybrid engine. “The hybrid engine is conceptually a mathematical equation solver. Figure 5-18 can depict the hybrid simulation engine architecture of AnyLogic. The discrete simulation engine generates a set of global algebraic differential equations and sends it to the mathematical solver. Based on predefined statechart and model settings, the results of the solution would indicate a threshold value has been met or a condition satisfied, then a change event occurs and the model makes the appropriate state transition" (Marin et al., 2010). Condition checking is done at each time step. (AnyLogic.com). "If condition is true then a triggering event is generated and a transition is enabled. Otherwise the calculations continue to update the continuous variables until the next discrete event" (Maler et al., 1992).

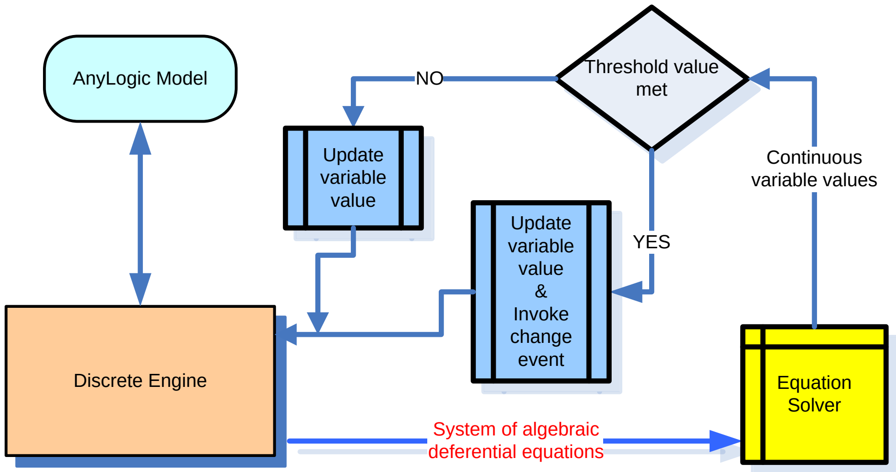


Figure 5-18. AnyLogic's hybrid architecture.

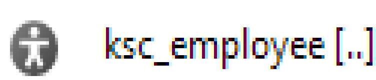
"The system state changes only by events and these events can be generated because of some continuous variables in the system. All events are timeless. Thus AnyLogic updates the state of the system in a discrete way only". Otherwise a pure discrete model would just jump between the events' time stamps (Marin et al., 2010). "AnyLogic has the property to advance time during the phase that is continuous. The system state does not change until the end this phase. However, this can also occur during the change event due to the computational process. In either case an event would trigger a transition that changes the system state" (Marin et al., 2010). After these changes, it follows the phases alternations described by Maler et al. (1992).

5.1.7.2. <u>The NASA KSC Agent Based Simulation using Anylogic</u>

The NASA KSC case study provides the background information required to develop the architecture that will be used in order to create a the simulation model that can support the simulation of the NASA KSC workforce environment and all elements within it to allow exploration of enterprise system-wide impacts. In addition, the utilization of the concepts of role-based simulation and the respective NASA KSC enterprise business rules and interactions were taken into consideration.

Representing entities in AnyLogic™ for NASA KSC simulation is accomplished by comprising abstract system specifications made of functional components of the workforce, in terms of their behaviors and interactions. The architecture for the NASA KSC model is composed of agents which are the most important objects of the system. These agents change from state to state based on events triggered by the parameters and decisions made by themselves, amongst themselves and/or by interactions with the environment. In addition, these events could be externally originated or internally caused by their own dynamics. These agents states are also affected by series of messages exchanged amongst them and are also affected by the set of parameters set for y the simulation system itself. Agents may share states and resources with other agents or objects. For our purpose, the agent based simulation model of NASA KSC is composed of:

- **Objects**: KSC Environment, which is the space where the simulation will take place. It is represented by  .
- **Agents:** KSC Enterprise (human resources), NASA KSC Employees.

  Represented by: 

  , 

- **Parameters:** the parameters of the simulated system are listed in the following table:

Table 5-4. Parameters.

Parameter	**Value**
Gender	0.50
Age	> 22
BaseHireRate	0.05
BaseWFRRate	0.10
ProbabilityOfLayoff	0.40
ProbabilityOfRetire	0.40
ProbabilityOfNewjob	0.20
retirerate	0.40
newjobrate	0.20
layoffrate	0.40
hirerate	0.10

- **Messages:** there exist a set of messages to be exchange amongst agents for the purposes of hiring new employees of for the purpose of reducing the workforce. Some of the messages to be used are depicted in the following table:

Table 5-5. Agents Messages

requesthire	requestWFreduction
thereAreRequests	thereAreRequests1
getRequest	getRequest1
Update employee database	LeavingKSC_notification
Check resource requireement	Generate new employee as needed
Leaving KSC	Employee_laidoff

In order for the agents to interact in the NASA KSC simulation system, a series of messages are exchanged amongst the agents in the system. First the KSC Enterprise agent (hr) checks to see if any system messages exists for either workforce reduction wfreduction or if any new hiring hire is needed. The next step, has the KSC Enterprise agent (hr) either entering the hiring state of new employees or send the message to the existing employees to transition to a workforce reduction state of retirement (retire) or be laid off (forced-out) or leave for a new job (moving_on). Following this transition, the agent would then leave the system. leaving_KSC Figure 5-19depicts the message sequence diagram of the NASA KSC model where a new employee is generated as hiring occurs.

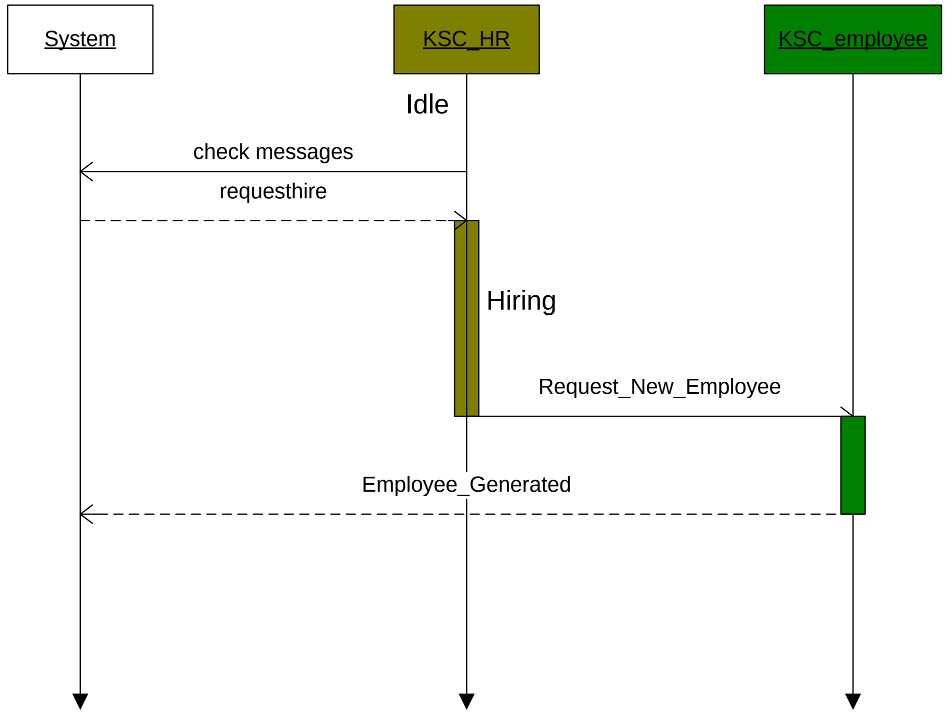


Figure 5-19 Message sequence diagram of the NASA KSC model.

The KSC Enterprise agent's state transitions according to the messages received form the other agents in the system and from particular events of the system. As soon as messages are received, this agent experiences a transition on moves to a new state. In our case study, the initial state (hr_atwork) of the KSC Enterprise agent (hr- human resources) is an idle state, as soon as the message/request is received to either reduce the workforce (wfReductionRequest) or to hire an employee (hireRequest) then the state changes to a hiring state(hr_hiring) or reducing the workforce (hr_wfr). Additionally, the reducing workforce state enters either of 3 different states: layingoff employees (hr_layingoff), retiring (hr_retiring) or sendingoff an employee who is leaving for a new job (hr_interview). Figure 5.20 depicts the KSC Enterprise agent state transitions.

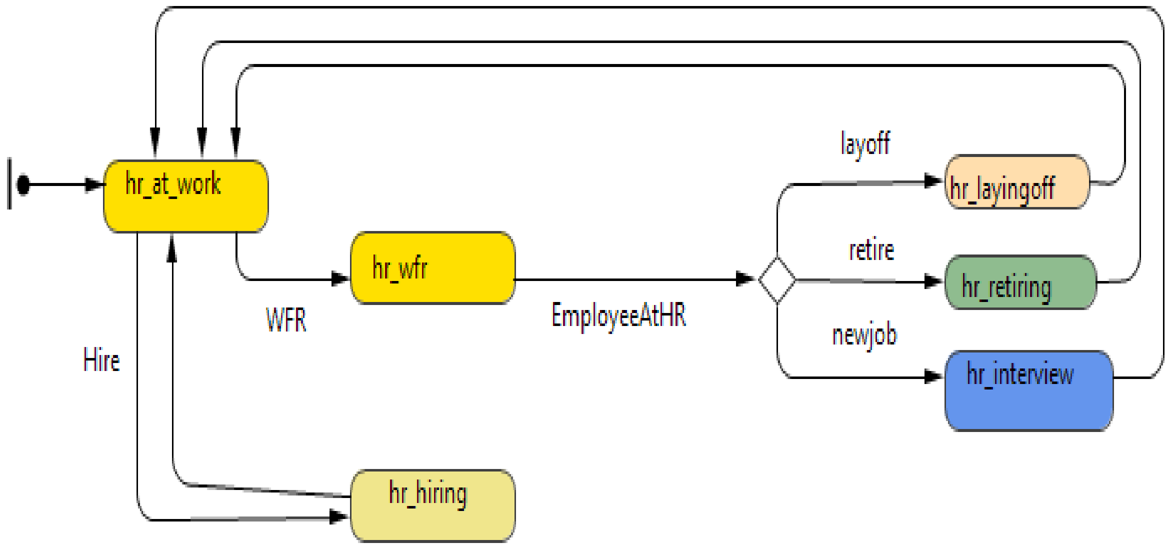


Figure 5-20 KSC Enterprise agent state transitions.

The KSC employee agent's state transitions according to the messages received form the other agents in the system and from particular events of the system. Initially, the agent checks his/her age and either stays in its current age group or moves on to the next age group. If its age is greater than 70 years old then the agent leaves the system. Additional transitions can be triggered by workforce reduction messages which mean leaving the system. This agent will transition to a state of either retire (retiring), leave NASA KSC for a new job (moving_on) or be laid off (forced_out) then the agent will leave the system (leaving_KSC). Figure 5-21 depicts the KSC Employee agent state transitions.

Our ABS simulation includes all characteristics of employees and the NASA KSC enterprise itself. These characteristics are represented in the model as variables that affect the behavior of the KSC employee agent and KSC employer simulated in our system. These variables in the system include employee's ages by group and their characteristics, the corresponding hiring rates for each age group, the corresponding attrition rates for each age

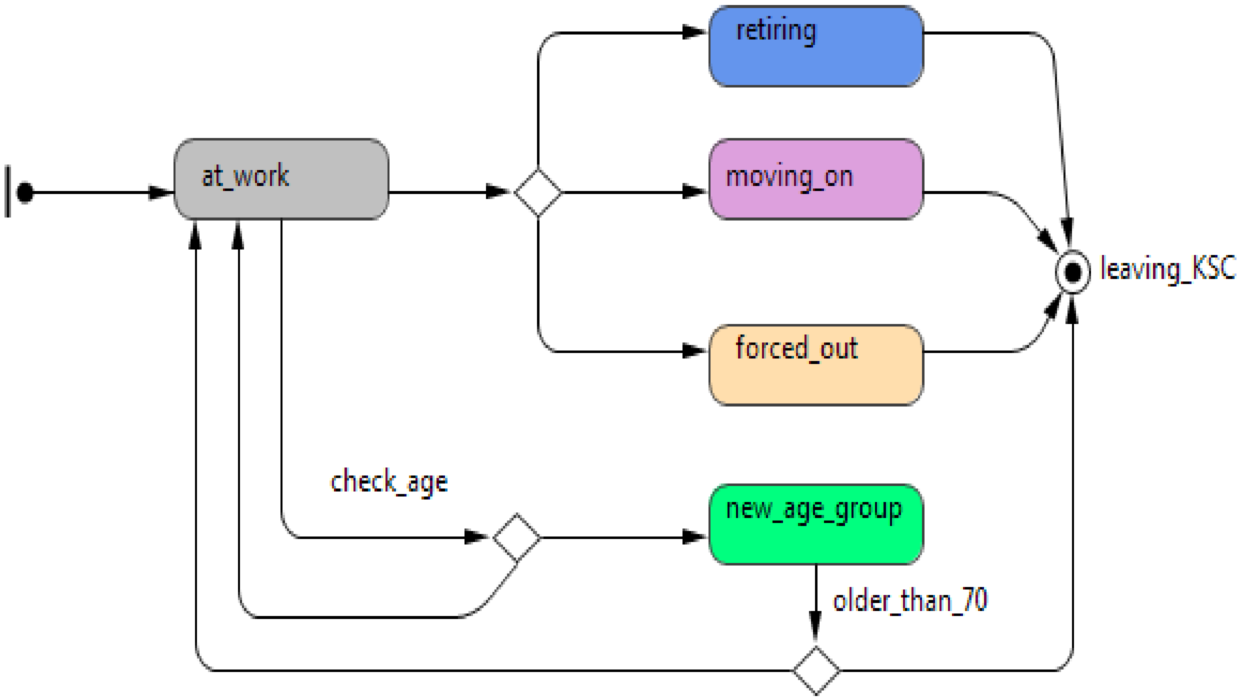


Figure 5-21 KSC Enterprise agent state transitions.

group, the NASA KSC requirements as dictated by the OMB (Office of Management and Budget) and NASA HQ (Headquarters) which includes a maximum hiring rate (maximum number of employees to be hired). Other factors that are part of the simulation variables mix include: the forecasted attrition numbers for every year. The projected periodic or permanent hiring freezes to be implemented and the percentage of other than permanent employees to be hired for the years in question. Table 2, lists the variables included in the simulation system.

The ABS simulation includes all the characteristics of the NASA KSC employees and KSC Enterprise characteristics (project requirements). The agent animation as depicted in figure 5-22, displays:

- Age
- Employment status
    - Newly hired

- FTP – OTFTP (total number)

- Gender
- State changes
    - age change, retiring
- Total number of agents per age group, per gender

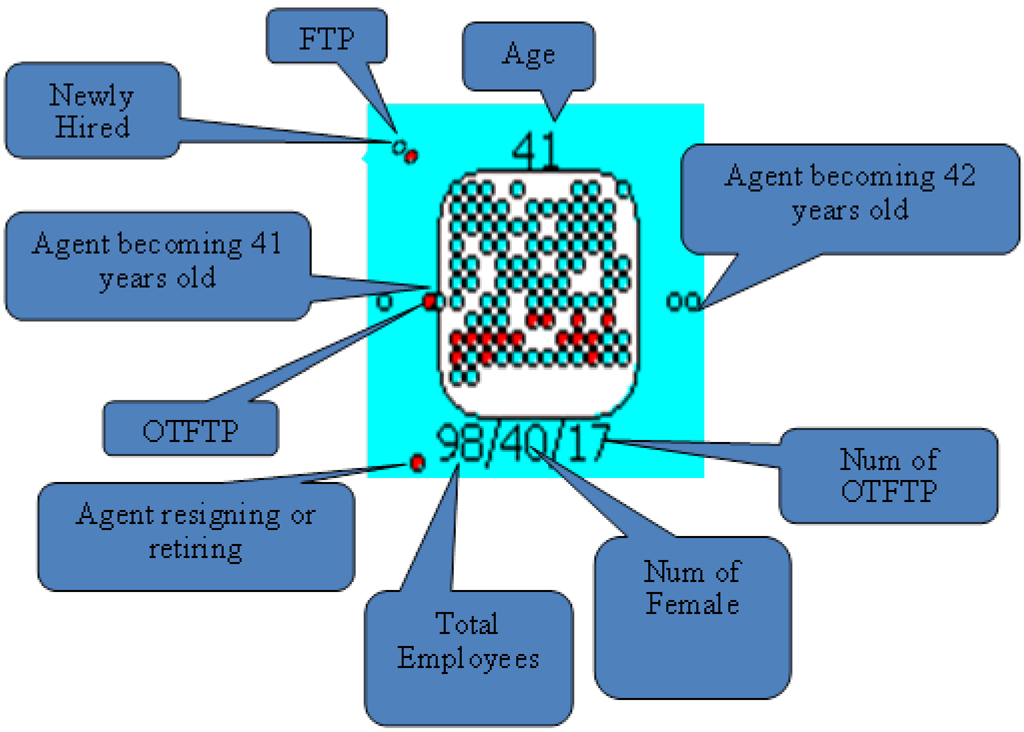


Figure 5-22. The simulation agent animation display (This user interface was programmed in Java and suggested by Mr. Yanshen Zhu)

This research effort model provides KSC management with a GUI (Graphical User interface) which can be run on line, here the different hiring strategies can be implemented. The hiring manager can set the simulation parameter for the agent variables to reflect a certain set of requirements for a program or project. The parameters include (Figure 5-23):

- Máximum hiring rate

- years to simulate
- attrtition rates
- yearly hiring freezes
- resource requirements number (HQ or OMB)
- alternate hiring schemes (OTFTP)

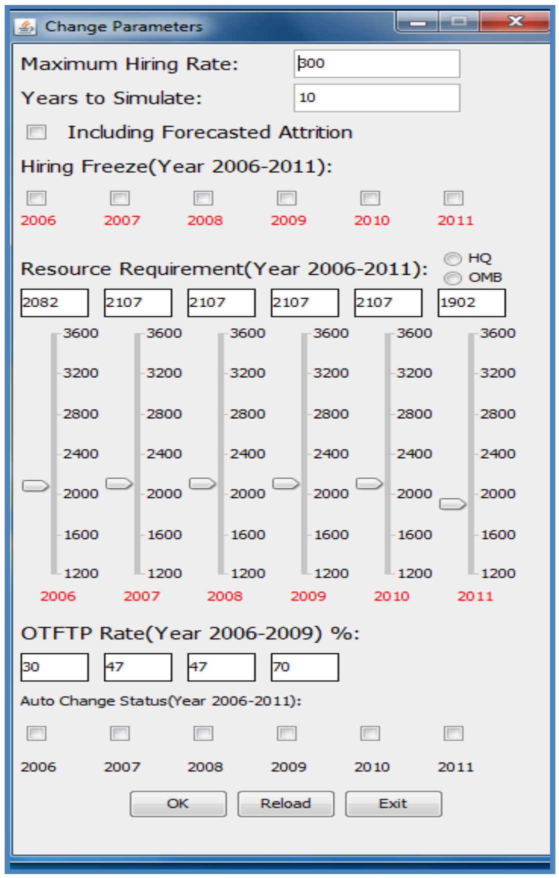


Figure 5-23. ABS Initial Parameters GUI

After the simulation run has taken place, the GUI (Figure 5-24) provides a set of KSC workforce variables which management can change to display the results according to certain agent variables (Table 5-6) along with attrition rates, age attributes and hiring rates. A graphical display (Figure 5-25) clearly shows the state of the workforce according to those variables of interest to them.

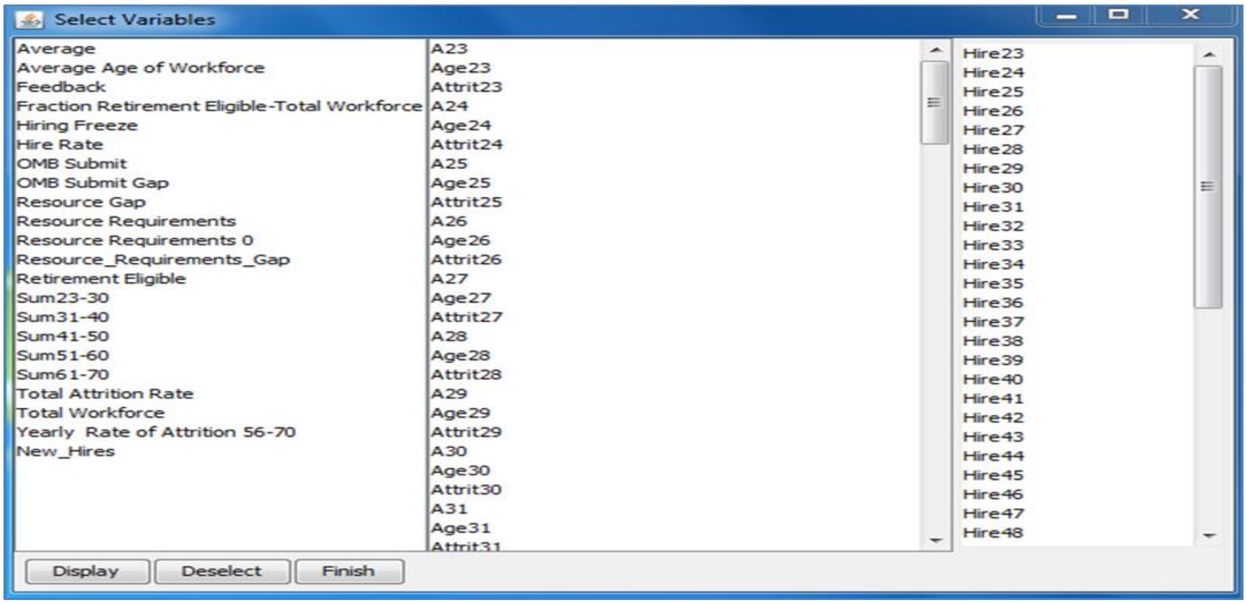


Figure 5-24. ABS Variables Selection GUI

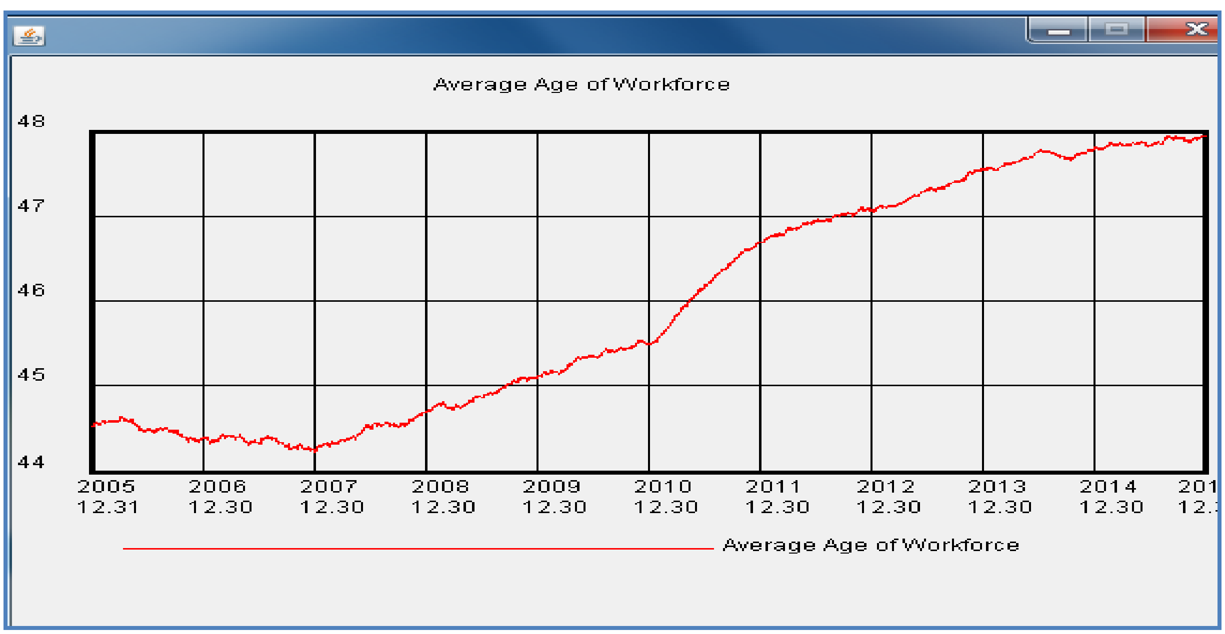


Figure 5-25. Average Age of Workforce

Table 5-6. NASA KSC Employee/Employer Variables

KSC WF Variables
Average
Average Age Workforce
Feedback
Fraction Retirement Eligible
Hiring Frezze
Hire Rate
OMB Submit
OMB Submit Gap
Resource Gap
Resource Requirements
Resource Requirements Gap
Retirement Eligible
Sum 21-30
Sum 31-40
Sum 41-50
Sum 51-60
Sum 61-70
Total Attrition Rate
Total Workforce
Yearly attrtion rate
New Hires

5.1.8. Analysis and Policy Development

After the initial analysis of the state of the NASA Enterprise, the SD models showed the critical situation that management was about to face because the NASA KSC budget was being drastically reduced therefore funds were not going to be available then (2005) and in the near future (2005-2010). There were no funds allocated down the horizon for space vehicles or NASA KSC programs. Some policies needed to be derived and implemented in order to avoid having to layoff the NASA KSC workforce. By analyzing the state of the workforce and its characteristics, along with the future requirements the needs were there to be fulfill in order to upkeep productivity across the space agency.

A new strategy was thought of and implemented through the use of the ABS simulation model developed. It includes the different variables and parameters that allow the hiring of new employees on a modified FTP status. The employees would come on board being OTFTP that would stay on temporary bases for a maximum of 2 years; they would them be assessed and evaluated for the chance of being offered a FTP position or for ending the temporary work assignment of 2 years.

5.2. Validation of Framework (Observation)

After implementation of the new hiring strategies proposed by management taking into consideration and applying what the framework parameters allowed and the experts opinions and recommendations of NASA KSC management personnel, it was demonstrated as depicted in Figure 5-26, that the results clearly show where that sector of the workforce is going to be at the time period of concerned simulated. The initial number of OTFTP employees in the year 2005 (Year of initial analysis) was just above 300, it declined for the following 2 years and remained constant for the following 2. Ultimately, the simulation shows the additional decline from the year 2009 through the year 2011 when the number of employees needed (OTFTP) was reduced to zero.

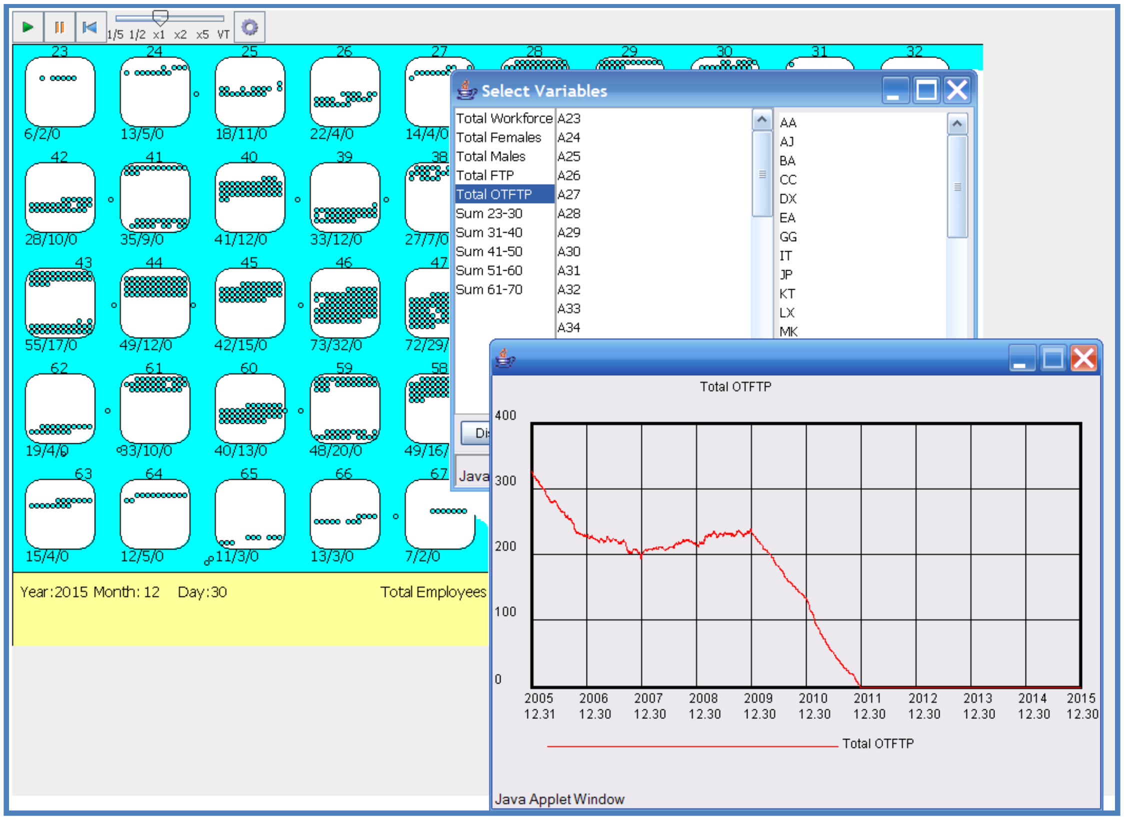


Figure 5-26. OTFTP Section of Workforce (This user interface was programmed in Java and suggested by Mr. Yanshen Zhu)

CHAPTER 6. CONCLUSIONS

6.1. General Overview and Conclusions

The Agent Based Simulation based on results of the System Dynamics simulation of the NASA KSC workforce environment represents the state of the workforce. This research effort developed and presented the framework for improved managerial decision making and prediction of workforce needs and trends that incorporate NASA KSC system complexity interactions and dynamic behavior models.

The literature review presented the current approaches of simulation and techniques other than simulation that deal with Workforce Management. This effort has found for workforce management issues, there is not a comprehensive approach that takes into account: uncertainty, complexity, workforce component interactions; that models and analyses behavior thoroughly; that analyzes the state of an organization's workforce and its components; that optimizes organizational policies and that analyses the workforce at different resolution levels. This research effort used systems dynamics modeling and agent based simulation in order to account for system component complexity and to provide an organization with optimal policy strategies that include the analysis of: human capital available, overall enterprise resources, and work climate dynamics. Additionally, this research effort provides an user interface which management can effectively use to see where its workforce is going to be at any period of time. Workforce management personnel can use alternate approaches that include project requirements and financial limitations in order to plan and predict workforce needs and trends of the coming years.

In conclusion, workforce management is very difficult to deal with. The approaches that have been used do not capture all the factors that have influence on such an important part of an enterprise and do not represent all the characteristics of today's workforce environment components. Our framework introduced the use of SD and ABS techniques that facilitated the creation of models that thoroughly represented the workforce environment and its components.

The NASA KSC study validated our framework approach which provided a sound analysis of the state of the workforce that accounted for all the variables and characteristics of workforce components and the NASA KSC enterprise. The framework facilitated the conditions for the agent model design to take into consideration all variables and characteristics and allowed management to place into action the new hiring policy that was feasible. By allowing the adoption of alternate employee status (OTFTP-other than full time permanent), the enterprise was not mandated or committed to maintain, for more than two years, in its payroll and benefit plan at a percentage of the new employees it hired. Management had the flexibility of either transition the employee to a permanent position (FTP- Full Time Personnel) or to end the employment assignment at the completion of the second year. This strategy was approved by management, recognized and validated by NASA KSC experts opinions as a way to effectively meet the requirements of the existing programs and the budgetary restrictions of the time.

6.2. Framework (Summary)

Our framework (Figure 6-1) as explained in Chapter four after analyzing the challenges presented by the research question and the facts learned during the literature review process. The starting point of the research dealt with the assessment of the workforce through an initial data mining and analysis process. It continues with brainstorming sessions between different through several brainstorming sessions with interdisciplinary groups and the enterprise workforce environment groups. These processes allowed to the development of workforce causal loops and the stocks and flows.

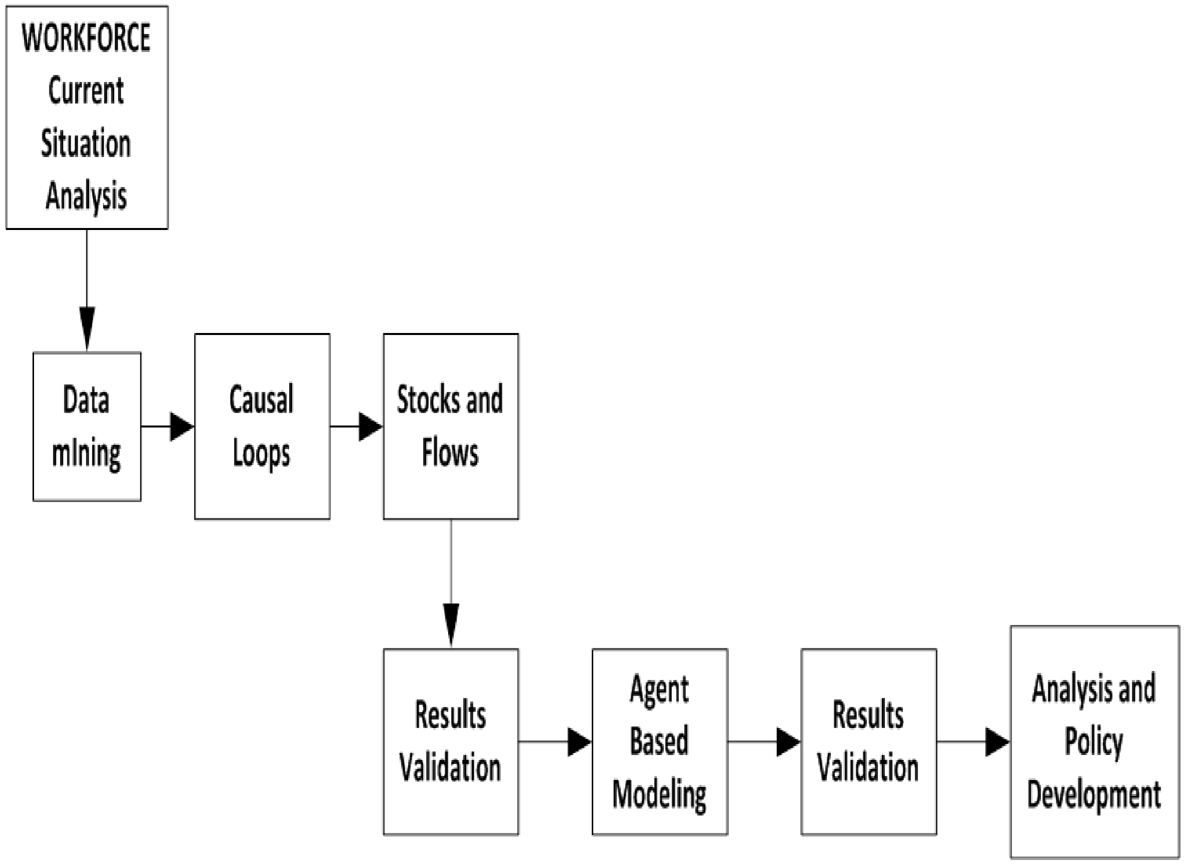


Figure 6-1. Framework for workforce's strategies analysis

The above mentioned sessions took into considerations workforce variables that helped lead to the development of simulated workforce state that showed where the workforce components were at in relation the factors that influenced it. The framework results showed one fact that stood out, the enterprise would had apply alternative hiring strategies in order to meet project requirements and available financial resources. These results provided conclusions for comparison of workforce status and also determined the bases for the ABS simulation model.

This ABS model was developed and permitted the development and implementation of alternate hiring policies that provided a clear picture of the future of the workforce.

6.3. Contributions to the Body of Knowledge

The research effort has develop and validated a framework for decision making in workforce management that measures workforce demand and forecast, that perform alternative selections, and analyze the dynamic behaviors of workforce components. It provides a way to establish a comprehensive decision-making methodology that managers can use to develop workforce strategies.

This framework provides a comprehensive, multi-resolution, dynamic models of the different areas of an enterprise's workforce. The ABS simulation model has the capability to be built relative to work climates which include: human capital demographics, project environment, project management, enterprise safety, human factors, and enterprise system architectures operational/workforce requirements.

The contributions from this research to the body of knowledge are originated in the application of workforce planning strategies based on complexity of work environment behaviors using the simulation object oriented approach provided by the use of Statecharts associated with active objects at various levels of resolution. To accomplish this type of simulation, this research effort has employed the software AnyLogic™; this package indicates the state space of the object (KSC Enterprise workforce component) and the events that cause it to take transitions from a state to another, it can also provide descriptions of the actions that result from workforce components state changes.

The main contribution from this research come in the form of :

- A framework that allows management to tame workforce complexity based on planning strategies and work environment behaviors.

6.4. Further Research

The framework intends to demonstrate the integrated use of systems dynamics and agent based simulation to improve workforce management decision making. In order to continue improving the proposed methodologies for additional research we have included the following areas of future exploration:

- Use of MRM (Multi-resolution Modeling) approach to model entities at different levels of resolution.
- Develop SD models on top of ABS models to represent different domains.
- Apply SD and ABS concepts to manufacturing, healthcare and service related fields.

An additional area of research to be considered is the exploration of possible applications of our workforce management methodology to tackle issues related to the reduction of armed forces personnel. Given the facts that the war efforts have been drastically reduced over the last couple of years, there is going to be excess personnel (military and civilian) that were actively employed during that period of time.

APPENDIX: AREAS OF CONCERN VARIABLES

This appendix contains the information regarding the areas of concern that are taken into consideration by the interdiciplinary groups in their disccussions, meetings and brainstorming sessions regarding workforce factors.

COMMUNICATIONS CAUSAL LOOP	COMPLACIENCY CAUSAL LOOP	CONTRACTOR'S	HUMAN FACTORS CAUSAL	JOB SATISFACTION CAUSAL
Variables	Variables	Variables	Variables	Variables
Effective supervisory/employee	Willingness to accept risk	Safety	Negative stress	ffective leadership communicatior
Effective peer communications	Perceived safety	NASA productivity	NASA budget	Job security
Productivity	Good decisions	Award fee	Productivity	Job satifaction
Morale	Rumors / Speculation	Raid contractor	Schedule issues	Work/life balance
Employees trust	Framing	Launch rate	Motivation	Job content(mission)
Upward FB	Must save program	Contractor motivation	Turnover	Productivity
Effective supervisory/employee	ConfEvidence	Contractor productivity	Accidents/close calls	Burnout
Trustin environment	Schedule pressure	Quality	Quality	Work relatioships
Mentoring	Budget pressure	Rework	Time away from work	Role clarity
LMX	Political pressure	Contractor resources available	Human resources	Trust
Feedback Climate	Complacency	Hire	Rework	Respect
Peer relationships	Accident	Promote excontractors		Informal/Formal recognition
Teamwork	Technical Assesment	Contractor expertise		NASA achievement
Knowledge transfer		NASA skill mix problem		Unrealistic expectations
Clarification of goals		NASA resources requirements		Absenteeism
Knowledge management		More NASA experience		Motivation
Internal competition		Schedule issues		mployee commitment/engageme
		Risk of accident		Results
		Catastrophic event		Conflicting goals/priorities
		NASA motivation		Recognition
		Bad press		Schedule pressures

KNOWLEDGE CAUSAL LOOP	MOTIVATION CAUSAL LOOP	PERCEPTION OF KSC	PERCEPTION OF KSC	SCHEDULE PRESSURE
Variables	Variables	Variables	Variables	Variables
Skills mix problem	Motivation	Job security	Job security	Politics
Knowledge gap	NASA budget	Attrition	Attrition	Poor decisions
Attrition	Results	Perception of KSC	Perception of KSC	Available resources
Training	Productivity	Negative press	Negative press	Schedule pressures
Role uncertainty	Unrealistic Expectations	Launch rate	Launch rate	Technical assesment
New hires	Available resources	Results	Results	Willingness to accept risk
Mentoring	Need satisfaction	Productivity	Productivity	Accident
Knowledge transfer	Recognition	Percieved job security	Percieved job security	Launch rate
	Work	mployee commitment/ engageme	mployee commitment/ engageme	Launch slip
	New hires	Budget	Budget	Work backlog
	Internal competition	Accident	Accident	Motivation
	Fear relative position	Moativation	Moativation	Stress/fatigue
	Challenged	Supervisor relationships	Supervisor relationships	Unrealistic expectations
		Job satisfaction	Job satisfaction	Errors
		Trusts	Trusts	Rework
		Politics support	Politics support	

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