An Optimization Approach to Workforce Planning for the Information Technology Field

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PREFACE

The Army is under pressure to reduce its infrastructure, including the military and civilian workforce in the Table of Distribution and Allowances (TDA) organizations, by streamlining or outsourcing major functions. For such fast-growing fields as information technology (IT), which face rapid technology changes as well as challenges in recruiting and retention, outsourcing might be especially appropriate in some cases. At the same time, however, the Army may need to preserve some IT competencies within its own structure. To balance the competing goals of reducing infrastructure and preserving skills, the Army must carefully manage military, government civilian, and contractor workforces.

The Army currently uses linear programming to study some aspects of overall military personnel management. This report describes a linear programming framework that helps explore the cost and personnel consequences of management decisions that change the structure of the IT workforce—in particular, the possible effects of increasing the use of government civilians or of outsourcing IT functions to civilian contractors. The approach can help Army personnel specialists better understand the effects—both intended and unintended—of policy changes.

This report should be of interest to the Office of the Secretary of Defense and to Army policymakers involved in developing strategic human resource plans that effectively use military, government civilian, and contractor personnel. This research was sponsored by the Office of the Assistant Secretary of the Army (Manpower and Reserve Affairs) and was conducted in the Manpower and Training

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A February 2000 report on Human Resources Strategy produced by the Defense Science Board noted that rapid downsizing in recent years has changed the roles of, and balance between, DoD civilians and military personnel, as well as the roles of government and private-sector personnel (DSB, 2000, p. vi). Because of these changes, the board called for the development of a strategic human resources plan that effectively uses military, government civilian, and contractor personnel. Effectively managing these three sources of manpower is especially important for the Army in the information technology (IT) and information assurance (IA) fields. This report presents a linear programming approach to modeling the IT/IA workforce that will help identify the potential costs and benefits of policy changes that affect how these personnel resources are used.

The transformed Army of the twenty-first century will increasingly depend on "digitized" tools, such as the Army Battle Command System (ABCS), a vast system of interconnected computers that will provide commanders with a common picture of the battlefield. The Army's 2001 Force Design Update[1] anticipates that the increased reliance on such systems will require an active-duty Army TOE IT/IA workforce more than two and one-half times larger than the current one.

But the TOE workforce is not the only part of the Army that will be affected. Currently, 80 percent of the Army's authorized civilian and

[1]A s shown in the out-of-cycle Force Design Update presented to the Senior Information Officers Review Council on March 26, 2001.

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military IT/IA positions are in the TDA workforce, and increased dependence on IT may affect personnel needs in these areas as well. In addition, Army surveys show that almost 25 percent of the current IT/IA workload is accomplished by a "shadow" workforce—personnel accomplishing IT/IA tasks that are outside of their "officially" assigned duties. The existence of the shadow workforce may indicate that IT professionals are already overworked, that training requirements in some non-IT fields need to be modified, or that other inefficiencies are in the workforce, so the consequences of increased IT/IA demands may involve more than the personnel increases required for ABCS.

Potential increases in IT/IA personnel requirements pose challenges for several reasons. Although IT/IA military occupational specialties are not experiencing broad shortages at this time, some senior warrant officer positions remain unfilled, and anecdotal evidence indicates that enlisted retention will decline. IT specialties command higher salaries in the commercial world, and some enlisted personnel will take advantage of IT training in the Army to obtain higher-paying civilian jobs after their initial enlistments are up. Government civilian IT specialties are also experiencing troubling trends as their workforces age, and relatively low government salaries make the recruitment of new IT professionals difficult. Finally, the Army is under some pressure to reduce costs and decrease its infrastructure by streamlining or outsourcing some major functions. Some IT/IA functions may be reasonable candidates for outsourcing, but increasing requirements could complicate the process.

In light of the Defense Science Board's (DSB's) recommendations to develop plans that effectively use all sources of personnel, two key questions should be addressed:

- What are the cost and assignment consequences of shifting TDA positions from the military to government civilians?
- What are the cost and assignment consequences of increasing outsourcing by allowing more contractors to fill positions formerly limited to government civilians?

The Army of the future will need to accomplish its IT/IA tasks within the constraints of available personnel and budgets. Doing so may require changing how government personnel are used or increasing the use of contracted personnel. In addition to getting the job done, the Army might want to minimize costs or optimize some other measure of performance. These requirements together describe a "classic" linear programming problem: to optimize an objective within given constraints.

Using Fort Bragg as a test case for a typical Army installation's IT/IA personnel structure, this report develops a basic linear programming approach to studying the consequences of IT/IA personnel policy changes. The basic idea of the model is to achieve a certain objective (such as minimizing costs of the workforce) while ensuring that all IT/IA jobs are filled. The model structure makes it easy to introduce different personnel policy constraints, such as limitations on assignments for government civilians, and observe the effects on the costs of the workforce. It is also easy to analyze how assignments might change by occupation when a policymaker's objective (such as minimizing costs or maximizing the number of military personnel in certain positions) changes.

RESULTS

The three most important conclusions to be drawn from this report are that the consequences of policy changes can be quantified, a variety of scenarios can be easily developed and studied using linear programming, and modeling in this way can give a policymaker insight into the effects of proposed personnel policy changes. This report focuses on three problems:

- Estimating the costs of the shadow workforce.
- Estimating the costs of the increased workload expected because of the introduction of ABCS.
- Analyzing the consequences of different approaches to dealing with personnel limits, specifically, a 90 percent fill rate for authorized positions.

As presented here, the first two problems do not require linear programming to maximize an objective. They merely show that the structure of the program allows these costs to be estimated. However, if an analyst started with these baseline estimates and wanted to experiment with different personnel assignment policies, the model could easily determine which assignments should be made to minimize costs.

The third problem shows the real usefulness of the linear programming approach by describing how different constraints on a problem can lead to quite different solutions. In one scenario, in addition to the 90 percent fill rate, we assume that the unit can change assignment policy but must not exceed current government civilian personnel inventories. In the other, we assume that the government civilian inventories can be adjusted, but the current personnel budget cannot be exceeded. The second scenario, which might seem more restrictive, leads to a lower-cost solution, and the differences in assignments by grade made by the model are quite complicated.

RECOMMENDATIONS

Although we discuss detailed scenarios only for Fort Bragg, we also describe how the model could be extended to broad Army "archetype" installations to study the complex interactions of personnel availability and assignments in an Army-wide setting for installations of varying missions. This type of extended model would be extremely useful in any strategic human resources plan for the future.

ACKNOWLEDGMENTS

We are grateful to the XVIII Airborne Corps and the Garrison Staff at Fort Bragg, North Carolina, for agreeing to let us conduct interviews with several organizations on the post to learn more about IT workforce issues. We especially appreciate the efforts of Sara Morgan of the Civilian Personnel Office at Fort Bragg, who hosted our visit and arranged meetings with members of the general staff and various garrison activities. Fort Bragg's cooperation helped us gain insight into current IT issues that contributed to the design of the linear programming model used in our analysis. We are also grateful to our reviewers, Harry Thie and Andrew Loerch, whose detailed comments improved the presentation of this material.

Major Patrick Kirk, Army RAND fellow from September 2000 to July 2001, was instrumental in collecting the Army personnel data necessary for the analysis in this report.

ACRONYMS

ABCS	Army Battle Command System
ADP	Automated Data Processor
AMCOS	Army Military-Civilian Cost System
BAHR	Businesses of Adams, Hargett, and Riley (Inc.)
CALL	Center for Army Lessons Learned
CASCOM	Combined Arms Support Command
COSCOM	Corps Support Command
CPS	Current Population Survey
CSS	Combat Service Support
DISCOM	Division Support Command
FBCB2	Force XXI Battle Command—Brigade and Below
FY	Fiscal year
GAMS	General Algebraic Modeling System
GAO	General Accounting Office
IA	Information assurance
IPT	Integrated process team
IT	Information technology
JV	Joint Vision
MEO	Most efficient organization
MOS	Military Occupational Specialty

ODCSOPS	Office of the Deputy Chief of Staff for Operations and Plans
OSD	Office of the Secretary of Defense
POSCO	Position Code (file)
TDA	Table of Distribution and Allowances
TOE	Table of Organization and Equipment
SETA	Systems Engineering/Technical Assistance
USAAA	U.S. Army Audit Agency
USACEAC	U.S. Army Cost and Economic Analysis Center

Chapter One

INTRODUCTION

Over the past several years, a variety of federal government and Department of Defense publications have addressed the information technology (IT) and information assurance (IA) needs of the military. The General Accounting Office (GAO) published *Information Security: Computer Attacks at Department of Defense Pose Increasing Risks* in May 1996, and the Defense Science Board summarized threats to the government's information infrastructure in its 1996 *Report on Information Warfare—Defense*.[1] These and other reports led the Office of the Secretary of Defense (OSD) to establish an Integrated Process Team (IPT) to address the human resource issues raised by these threats—specifically, the needs to identify critical IT/IA skills, establish well-defined occupational descriptions and career fields, monitor accession and retention trends, and implement training programs to ensure acquisition of proper skills.

According to the IPT's final report, which was published in 1999, a worldwide shortage of IT professionals increases the competition for skilled personnel and complicates the government's (particularly the military's) task of hiring people to maintain its information infrastructure (*Final Report,* 1999, p. 1). Because of the potential difficulty of maintaining this infrastructure, the IPT concluded that threats to government information systems, aggravated by personnel short-

[1]Both reports stress DoD's increasing reliance on information infrastructures, and the potential threats raised by this dependence.

ages, make the prospect of achieving the information superiority goal of Joint Vision 2010 (JV 2010) "bleak" (*Final Report,* 1999, p. 1).[2]

Because the Army's planned "transformation" will increase dependence on personnel with IT skills, Army personnel experts have been studying the current state of accession and retention for IT Military Occupational Specialties (MOSs) and civilian personnel fields as well as anticipated future needs for the transformed Army. Additionally, the Army is under pressure to reduce costs and decrease its infrastructure by streamlining or outsourcing some major functions. Some IT functions, especially rapidly changing ones in which the private sector can maintain currency more easily than the military can, may be reasonable candidates for outsourcing. However, increasing requirements in fields that are required to employ military personnel exclusively could complicate the process.

Current shortages in some specialties, potential difficulties in recruiting and retaining IT/IA specialists—both military and civilian—and the possibility of increased reliance on contracted personnel to provide services make it important to use careful management practices to ensure that the IT needs of the Army are met. Shaping the IT/IA workforce for the future may also require reconsideration of the "total" workforce structure, including options to move contractors and civilians into roles previously reserved for uniformed military personnel.

Study of different options for force management must take into account budget, legislative, and personnel constraints, and these constraints can sometimes interact in complex ways. The purpose of this report is to describe a linear programming analytical framework that can be useful in studying the personnel assignment and cost consequences of policy changes made in an effort to maintain minimum IT/IA requirements.

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[2]JV 2010, released in February 1997 by General John Shalikashvili, Chairman of the Joint Chiefs of Staff, is a "conceptual template for future joint operations" in the twenty-first century. JV 2010 has four operational concepts—dominant maneuver, precision engagement, focused logistics and full-dimensional protection—and two "enablers"—technological innovation and information superiority. Joint Vision 2020 (JV 2020), which builds on the ideas of JV 2010, was released in May 2000. The JV 2020 document is available on the Internet at http://www.dtic.mil/jv2020/jvpub2.htm.

ANALYTIC APPROACH

This project began as work with the Assistant Secretary of the Army (Manpower and Reserve Affairs) to develop a framework for estimating personnel requirements in IT/IA and for assessing alternative mixes of military and civilian personnel to meet the requirements. Initial discussions showed that the assessment of alternative workforces was the more important question, since the Army apparently had no systematic way of doing so for the military, civilian, and contractor segments of the IT/IA workforce.

A review of earlier RAND research and other literature suggested that linear programming would be a useful tool for studying alternative force mixes, and we developed a broad outline of how such a model might be constructed to study the Army as a whole.[3]

To test the ideas in the model outline, we first conducted interviews at Fort Bragg to get detailed information on the use of military, civilian, and contractor personnel in the IT/IA field and to learn more about perceived workforce shortages, assignment restrictions, and the potential effect of using more-advanced computer technology for military purposes in the future. Based on these interviews, we refined the structure of the linear programming model and used Fort Bragg as a test case in employing the model to study the consequences of policy changes and changes in workforce constraints.

OUTLINE OF THE REPORT

The rest of this report is divided into five chapters. After this introduction, Chapter Two provides background for the problem of fulfilling the IT/IA requirements of the Army. It discusses current IT/IA needs, anticipated changes stemming from the Army's transformation, potential difficulties in meeting those needs, and the motivation for considering alternative force mixes to meet them.

The next chapter describes a linear programming approach to modeling the problem. The description is general but includes important assumptions in the model and a discussion of model

[3]The Army has used linear programming to study distribution options for military personnel. See Sweetser (2001).

parameters (the compouter program itself can be found in the appendix).

In the Chapter Four, we discuss why Fort Bragg was used as a test case and detail insights gained from interviews with personnel managers there. We also discuss how salaries of civilian contractors were developed for the model. The next chapter uses the linear programming model to analyze several scenarios to show how a personnel specialist could study the consequences of changing personnel or fiscal policy.

In Chapter Six, we discuss implications of using the model and describe how it could be enlarged to assist in planning and evaluating alternative IT/IA workforces. An appendix details the implementation of the program model.

Chapter Two

BACKGROUND

In this background chapter, we will discuss current IT needs, anticipated increases, and potential problems with maintaining the workforce in the future. We will then address possible approaches to dealing with future challenges and why a new model to study the consequences of different approaches is needed.

THE SITUATION IN THE ARMY

Current IT Workforce

As of early 2001, the Army had approved authorizations for approximately 3,800 military personnel and 4,400 government civilian employees to support its requirements for IT and IA. These authorizations are Army-wide, including both Table of Organization and Equipment (TOE) and Table of Distribution and Allowances (TDA), and are distributed as shown in Figure 2.1.[1] Note that these autho-

[1]These authorizations are from the November 21, 2000, Position Code (POSCO) file, which is maintained by the Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS). An extract of the file was provided to RAND by ODCSOPS. The number of GS 2210 personnel is an estimate based on the IT/IA workforce study conducted by Businesses of Adams, Hargett, and Riley, Inc. (BAHR). The TOE prescribes the wartime mission, capabilities, organizational structure, and mission essential personnel and equipment requirements for military units. The TDA prescribes the organizational structure and the personnel and equipment requirements and authorizations of a military organization to perform a specific mission for which there is no appropriate TOE. (See the Army's Action Officer's Force Management Handbook, available on the Internet at http://www.afms1.belvoir.army.mil/aoh/index.htm.)

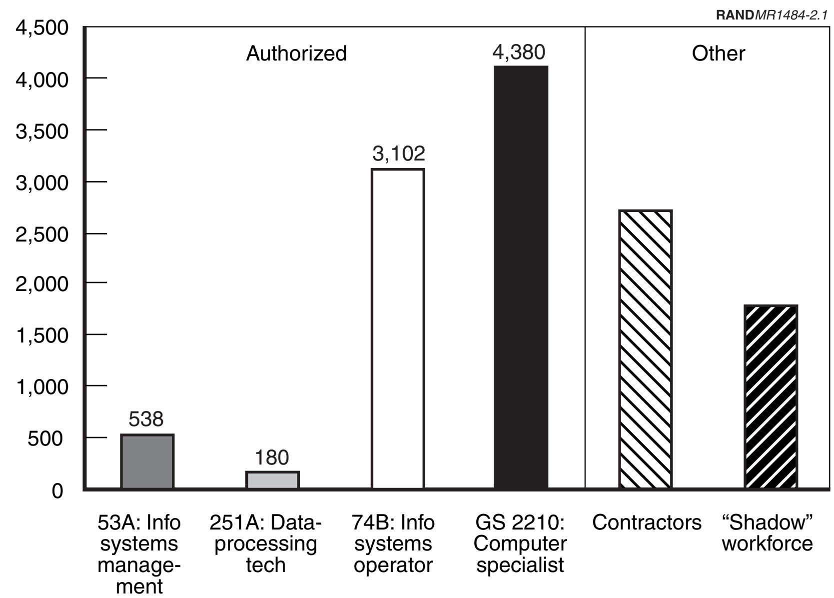

Figure 2.1—Current Army IT Workforce

rizations are restricted to the military occupational specialty (MOS) and civilian career fields specifically related to IT functions.

The Army does not centrally authorize contractor positions. However, an Army IT/IA Workforce Study completed in June 2000 indicates that at least 2,700 contractor personnel are performing IT/IA functions for the Army (BAHR, 1999). The same study indicates that “shadow” workforce personnel provide the equivalent of 1,900 full-time personnel performing IT/IA functions. “Shadow” personnel are those whose primary career field is not IT/IA but who perform some IT/IA function for at least 20 percent of their time.

Personnel in the “shadow” workforce fall into different categories. Some, mostly military, are personnel in a TOE organization with an IT/IA requirement, but the authorization and assignment process has not yet caught up to the requirement. Others, again primarily military, are performing essential functions that could be performed by government civilians or contractors but funding restrictions limit the ability to do so. These two categories can be considered temporary, in the sense that updated authorizations or funding would supply new personnel to accomplish the work. A third category consists of those, such as finance specialists, who perform some IT/IA functions as an adjunct to their primary specialty. This category is long-term in that it is preferable to teach necessary IT/IA skills to functional specialists rather than to teach the functional skills to IT/IA personnel.

Figure 2.2 shows the distribution of the authorizations between TOE and TDA organizations. A large majority of the authorizations (just under 80 percent) are in the TDA force.

ANTICIPATED CHANGES BECAUSE OF THE ARMY'S TRANSFORMATION

The Army is rapidly expanding its tactical digitization capability. Fielding of the ABCS has only just begun. This system is an inter-

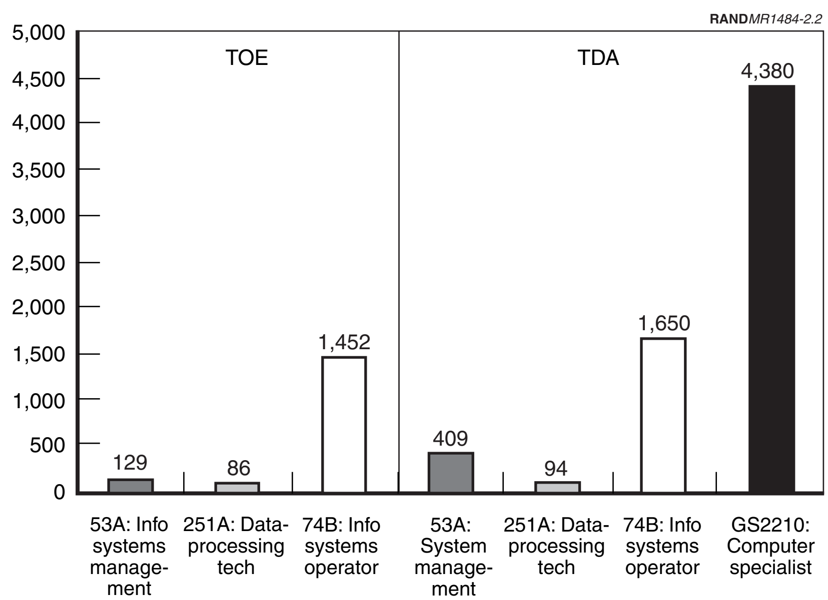

Figure 2.2—IT Workforce Distribution by TOE and TDA

connected collection of hardware and software systems designed to provide commanders at all levels with a common understanding of the battlefield. The key tactical component of this system is called Force XXI Battle Command—Brigade and Below (FBCB2). The FBCB2 component provides the electronic link between the front-line soldiers and commanders up to the brigade level. For this reason, it will be operated exclusively by uniformed personnel.[2]

The individual workstations in this system are designed to be operated by functional specialists and therefore do not generate an increase in IT/IA requirements. However, the system requires many and varied networks that must be established, interconnected, and maintained. Table 2.1 indicates the expected effect of those systems on the requirements for uniformed IT/IA personnel only in the TOE part of the active component of the Army. These requirements will phase in over several years. Similar increases will occur in the reserve components over a longer period.[3]

Clearly, such an increase in personnel and systems will generate an increase in requirements for support personnel in the TDA part of the Army, but no accurate estimate of the extent of that requirement can be made without further experience with the systems involved. No basis exists at present to estimate how the increased support force will be distributed among military personnel, government civilians, and contractor personnel.

Table 2.1

Current and Future IT TOE Workload in the Active Component of the Army

MOS/Career Field	Current Requirement	Requirement by 2010
53A Information System Management	129	335
251A Data-Processing Technician	86	320
74B System Operator	1,452	3,763

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[2]The Center for Army Lessons Learned (CALL) describes ABCS in Newsletter Number 01-18 (available at http://call.army.mil/). ABCS is also described in Army Field Manual No. 3-34.230, *Topographic Operations.*

[3]Data are from the out-of-cycle Force Design Update as presented to the Senior Information Officers Review Council on March 26, 2001.

WORKFORCE CHALLENGES

In March 2000, the U.S. Army Audit Agency (USAAA) published a "benchmarking" study on the IT workforce (USAAA, 2000). This was the conclusion of a series of audits related to the "digitization" of the battlefield, and it focused on recruitment and retention of personnel for the IT field. The study raises several issues that are important for the Army's forecasted IT needs.

For the current force, the study notes that the Army has no special problems recruiting enlisted personnel in the IT fields (31U and 74B) and retention rates are about the same as the Army average.[4] In the case of warrant officers (251A), the Army is experiencing difficulty in satisfying authorized requirements: in FY 1999 only 81 percent of those positions were filled.[5] Officer retention is a challenge for the entire Army, and the study notes a shortfall of captains in all fields. The signal branch loses more lieutenants than the Army average, but retention at other ranks is roughly the same as the rest of the Army.[6]

While these results might indicate that the Army's IT force is in no more trouble than the rest of the Army, anecdotal evidence raises concerns about meeting future needs. For example, interviews with enlisted personnel in the 74B MOS conducted as part of the benchmarking study revealed that many people were in the field only to get training and experience that would help them find jobs with private industry. Other interviewees commented that the possibility of changes in the occupation's mission that might require more work in the field than in an office environment might lead to lower retention rates.[7]

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[4]See USAAA (2000, p. 13). MOS 31U is Signal Support System specialist, which is not anticipating increases stemming from ABCS.

[5]This seems to be for reasons not necessarily related to IT. The study says that enlisted personnel who could move into these positions do not see any advantages in doing so. For example, some feel that the pay is not significantly greater than enlisted pay, while the responsibilities are closer to those of officers. See USAAA (2000, p. 23).

[6]According to the U.S. Military Academy's Web site, the Signal Branch provides "worldwide information systems and networks for real-time command and control of Army, joint, and combined forces in tactical, garrison, and strategic operations." (http://www.usma.edu/)

[7]Interviews were conducted with 109 soldiers, of whom 31 were in the 74B MOS. See USAAA (2000, pp. 18–19).

The apparent inclination of some enlisted personnel to use their Army training to help them obtain civilian jobs is understandable when the differences in potential earnings are considered. Figure 2.3 compares the present value of career earnings of several employee categories: individuals with high school educations in non-IT jobs, those with some college in non-IT jobs, those with some college in IT "core" jobs, those with four years or more of college and in IT core jobs, and enlisted personnel.[8] The financial rewards gained from

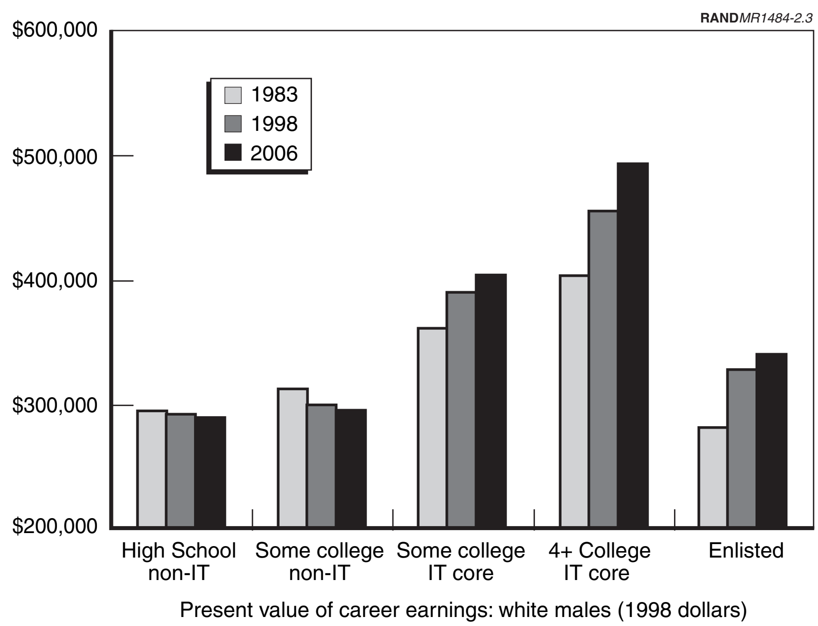


Figure 2.3—Career Earnings Comparisons for IT and Non-IT Fields

[8]This graph is from Everingham et al. (2000). IT "core" functions in this research were defined to be the following: information system operator, telecommunications computer maintainer, network analyst, small computer system specialist, information management, radio communications systems, and ADP repair.

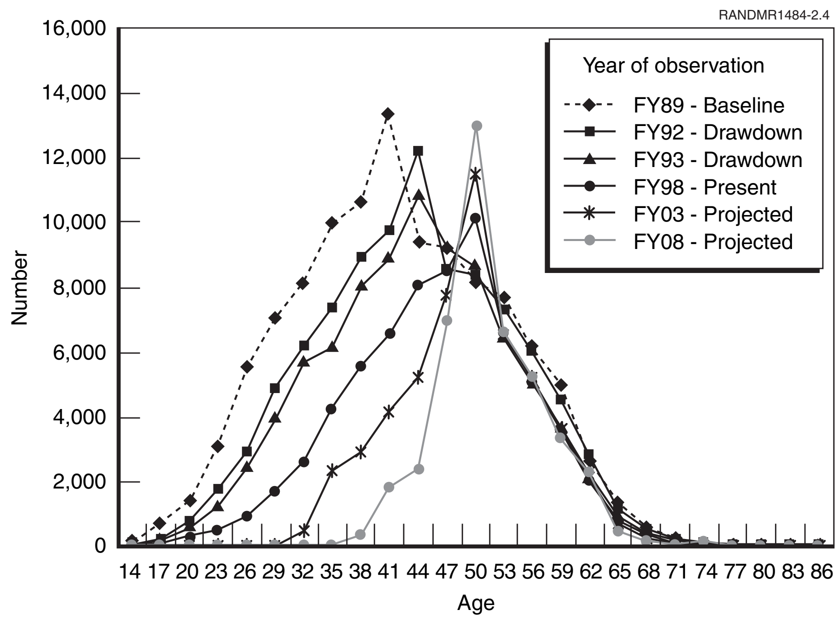
leaving the military are fairly clear in the enlisted case, with potential lifetime earnings (as a civilian with some college) close to 20 percent higher.[9]

However, potential difficulties in recruiting and retaining IT personnel exist not only for the military. The most important civilian IT fields are also experiencing some troubling trends—trends that affect civilian employment in the Department of Defense in general. The number of DoD civilian employees was cut from about 1.15 million in 1989 to approximately 730,000 at the end of FY 1999 as part of the overall DoD drawdown (DSB, 2000, p. 23). Most reductions were accomplished through early separation initiatives, voluntary early retirements, and placement programs that assisted employees in finding new jobs, and those who left were not replaced because of various hiring freezes or partial hiring freezes in effect from 1990 to 1994 (DSB, 2000, p. 23). As a consequence of the drawdown and freezes, the median age of the DoD civilian workforce rose from 41 in 1989 to 46 in 1999. Figure 2.4 shows the distribution by age of civil service personnel in the Army for selected years from 1989 to 1998 and projected distributions for 2003 and 2008. The median age of the workforce is expected to continue to increase.

While an aging workforce has advantages in knowledge and experience, it also raises fears of potential losses of that institutional knowledge if a large percentage of personnel retire in the next five years.[10] Replacing these experienced personnel might be difficult for a variety of reasons. The Defense Science Board report notes that budget constraints have limited programs used by the military services to recruit high-quality civilians (DSB, 2000, p. 37). The report also points out difficulties in attracting people to government service because of a lack of understanding of the role of civil service personnel in relation to political appointees and the military and a compen-

[9]The situation is similar for officers. Everingham et al. (2000) found that while mid-career officers (majors (O4) with 10 years of service) in non-IT career fields were in the 67th percentile of earnings for 32–36-year-old white males with four years or more of college, those in IT core functions were only in the 57th percentile.

[10]According to minutes from a December 4, 1999, meeting of the Army Information Operations General Officer Steering Group, 79 percent of the civilian IT/IA workforce can retire in the next five years.



SOURCE: Office of the Assistant Secretary of the Army, Manpower and Reserve Affairs, Civilian Personnel Policy, 1999.

Figure 2.4—The Aging Army Civilian Workforce

sation system that cannot offer market salary rates in competitive fields (DSB, 2000, p. 39).[11]

In a July 2000 briefing to the Army's Information Operations "Council of Colonels," the office responsible for professional development training for IT in the Army said that the civilian IT/IA workforce faces four challenges: [12]

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[11]All of these challenges are also noted in National Academy of Public Administration (2001).

[12] The relevant portion of the briefing was produced by DISC4 (SAIS-IMP). DISC4 is the Army's Office of the Director of Information Systems for Command, Control, Communications, and Computers. SAIS-IMP is the office for Professional Development Training. The date of briefing was July 13, 2000.

- Army and federal government cannot compete with private-sector IT/IA salaries.
- The federal hiring process is slow, preventing the Army from hiring talented candidates in a timely manner.
- On average, 55 percent of civilian IT/IA professionals who resigned from the Army (FY 1998 through the third quarter of FY 2000) took positions with the private sector.
- Those who resign for positions in the private sector tend to be better educated than those who remain in government service.

Problems with recruiting and retaining the proper personnel are aggravated by the lack of what the Defense Science Board report calls "the full range of authority and tools necessary" to manage the force as efficiently as possible. As if these problems were not enough, one of the frequently discussed solutions to the problem—outsourcing IT functions to civilian contractors—is viewed as such a threat to federal employees that it contributes to retention and morale problems in the civil service force.[13]

THE "SHADOW" WORKFORCE

The IA and IT Human Resources IPT mentioned above was asked to identify critical IT/IA skills and to recommend ways to maintain those skills in DoD. While trying to quantify the IT requirements and authorized billets to meet them, the team discovered that the military services assign to IT/IA duties many personnel not trained in IT functions. Three possible reasons account for this situation:

- There are insufficient authorized IT billets (and therefore insufficient numbers of IT personnel).
- There are authorized IT billets but insufficient personnel to fill them.
- There are non-IT specialties (such as finance and base supply) that, while technically requiring only non-IT expertise, increasingly demand IT skills (OSD, 1999, p. 5).

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[13]This point is made in the July 13 Council of Colonels briefing.

The Army had recognized the existence of "shadow" workforce personnel for several years before the U.S. Army Manpower Analysis Agency (USAMAA) conducted two surveys in 1999 in an attempt to determine the magnitude of the problem. As we saw earlier, a key finding of the surveys was that the "shadow" workforce performs almost 25 percent of the Army's IT/IA business.[14]

A shadow workforce has several consequences. First, the requirement for extra work that must be done by people not trained to do it could contribute to the perception of there being "too much work for too few people" that, according to the Benchmarking Study, causes "burnout" among Army IT professionals. Second, if people are finding it necessary to perform IT-related tasks as part of their other duties, it could indicate that training in certain career fields needs to be changed. For example, if finance offices are using more advanced computer tools, the Army could either train finance personnel to deal with problems common to those tools or expect finance personnel to depend on IT experts to solve them. It is probably easier for a financial expert to learn to solve problems specifically related to financial software than it is for an IT person to learn enough about finances to understand a software-specific problem. Finally, the shadow workforce could indicate inefficient use of the workforce. If non-IT personnel must perform IT functions, they must be trained to do so, and there may be hidden costs to the unit from time spent in the training. Costs also arise from time lost performing the IT duties instead of tasks related to an assigned function.[15] It is also possible that military personnel are being used for tasks that could be more efficiently or cheaply accomplished by government civilians or contractors.

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[14]The study defined the "shadow" workforce as persons not belonging to an IT/IA-related MOS, functional area, or career field but who spend 20 percent or more of their time performing IT/IA functions that are beyond their normal duties. This information is from a March 28, 2001, memo from DAMO-ODI (Office of the Deputy Chief of Staff for Operations and Plans, Information Operations Division): minutes of the March 26, 2001, Senior Information Operations Review Council meeting.

[15]More careful surveys to determine the extent of this problem might be in order. For example, people who reported spending 20 percent of their time on IT functions may have reported time spent on computers that helped them perform assigned duties.

SUMMARY OF WORKFORCE ISSUES

Transformation and "digitization" of certain functions means that the Army will increasingly depend on personnel with IT skills to accomplish its mission. While the Army is currently not experiencing difficulties in recruiting military personnel for these functions, there are indications and anecdotal evidence that military and civilian workplace pressures will make it more difficult for the Army to meet its needs in the future. Because much of the Army's IT work is done by government civilians, the aging civilian workforce and the difficulty in recruiting young people with the proper skills also have consequences for future mission accomplishment. Finally, a large "shadow" workforce hints that management and assignment of IT duties requires attention.

A perception exists in the Army that there is "more work than workers" as IT systems and infrastructure expand (and as evidenced by the shadow work force), and some retention/recruiting problems are emerging, with a loss rate of signal captains significantly higher than for the rest of the Army and shortages in midlevel NCO fields. Potential problems exist with the civilian workforce because of the large number of people approaching retirement and the fact that government wages are not competitive with the private sector.

These potential difficulties represent a challenge for future management of the Army's IT workforce, but they also provide an opportunity for exploring new approaches to IT workforce management. In examining the issue of managing civilian and military personnel for the Department of Defense, the Defense Science Board Task Force on Human Resources Strategy stressed that future force concepts must be linked to manpower requirements for the *total* force. It said, "In shaping the future workforce, priority must be given to providing needed capabilities from the most appropriate source—military or civilian, government or private sector" (DSB, 2000, p. vii). To assist in shaping the workforce, the task force recommended the development of a strategic human resources plan for military, civilian, and private sector personnel.

ALTERNATIVE APPROACHES TO SHAPING THE WORKFORCE

In keeping with the Defense Science Board's recommendation for shaping the force, several approaches could be taken to address potential Army difficulties in satisfying increased demand for IT services. Among them are the following:

- **Reconfigure assignments within the existing IT workforce.** Although TOE units are considered "warfighters" while personnel in TDA positions provide institutional support, uniformed military personnel currently fill positions in both the TDA and TOE workforces. The transformation of the Army may force a reassessment of what constitutes support and where one must be stationed to provide it. For example, new computer systems used in ABCS might mean that some intelligence or combat service support functions can be performed farther away from the battlefield. As a result, some positions formerly requiring military TOE personnel could instead be filled with government civilians or contractors in TDA positions. This could free up military personnel for battlefield duties.
- **Change the composition of the Army IT workforce.** Initial development documents for much of the equipment for the "digitized" Army claimed that new equipment would not require increases in IT personnel. This opinion was based on the assumption that individual components of the ABCS suite would be simple enough for relatively unskilled personnel to operate. While this assumption has since been challenged, two aspects of the digitized force may warrant changes in its composition. First, the structure of the "system of systems" may change the roles of personnel who deal with them in such a way that supervisory positions will need to be adjusted as decisionmaking is relegated to lower levels. Second, increased familiarity and comfort with computer systems mean that less-specialized personnel will be able to perform some IT functions. These two changes could justify the substitution of junior officers for senior officers, warrant officers for junior officers, and enlisted personnel for warrant officers. Changing the grade mix in certain IT areas could produce a cheaper IT force.

- **Shift more positions to nonmilitary labor.** DoD Directive 1100.4, *Guidance for Manpower Programs*, says "civilian personnel will be used in positions [that] do not require military incumbents for reasons of law, training, security, discipline, rotation, or combat readiness, [that] do not require a military background for successful performance of the duties involved, and [that] do not entail unusual hours not normally associated or compatible with civilian employment."[16]

Outsourcing functions that have hitherto been performed by military personnel or government civilians is often seen as a way to reduce costs by contracting work to more-efficient specialists. Indeed, the Federal Activities Inventory Reform Act (FAIR) of 1998 requires each federal agency to make available to the public an annual list of activities that it judges to be not "inherently governmental," and these commercial activities can be considered for outsourcing using Circular A-76 procedures.[17] Congress has also been known to pressure the military services to outsource functions as a way to provide services more cheaply.[18]

For the Army, saving money is not the only reason for outsourcing, however. According to LTG William Campbell, who retired as the Army's Chief Information Officer in July 2000, "In the information technology world, there will always be a combination of someone

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[16]DoD Directive 1100.4, *Guidance for Manpower Programs,* August 20, 1954, paragraph 4, "Personnel Utilization."

[17]However, such consideration is not mandatory. An Office of Management and Budget (OMB) Response to Comment 1c, 64 Fed. Reg, 33927, 934 (June 24, 1999) says, "The inclusion of a function on the agency's inventory of commercial activities does not mean that the agency is required to compete the function for outsourcing. Rather, the FAIR Act in Section 2(d) requires each agency to review its inventory of commercial activities. Presumably, this review would include consideration of outsourcing, consolidation, privatization, other reinvention alternatives or maintaining the status quo. Not all commercial activities performed by Federal employees should be performed by the private sector, though all such activities should be inventoried under the provisions of the FAIR Act and Circular A-76. The decision as to which commercial functions represent 'core capabilities,' and thus should be retained in-house, remains with the agency head."

[18]A June 4, 2001, article in *Federal Computer Week* (on the Web at FCW.com) described a hearing before the House Armed Services Committee's Readiness Subcommittee in which the Army's Chief Information Officer was asked to develop a five-year plan to improve IT service while lowering costs, implying that outsourcing was one way to do it.

wearing a green suit and contractors." There have been cases, he said, in which outsourcing is the only solution to a shortage of military personnel.[19]

A 1994 RAND study of the use of civilians in the Gulf War noted that the role of civilians in the Army is changing, with more reliance on civilian personnel (both government and contractor) at the tactical/operational level than in rear, fixed-facility locations (Bondanella et al., 1994, p. 1). The study observes that this is true mostly in logistics operations, where civilians "could be integrated with units more susceptible to close combat."

As the Army increases use of computer systems in logistics, intelligence, mapping, and other support areas, the distinction between "forward" and "rear" locations will become less important. New functions and the ability to perform them in different locations will make it possible to use nonmilitary labor in positions previously reserved for uniformed personnel.[20] The perception of what functions are inherently governmental could change enough to lead to fairly radical new approaches to outsourcing IT work. In unpublished research work, RAND senior engineer Kenneth Horn and others have explored the possibility of spinning off some Army activities into federal government corporations.[21]

CONSTRAINTS ON WORKFORCE SHAPING

Each of the potential workforce-shaping approaches mentioned above has potential constraints on its application. Reconfiguring the TOE and TDA distribution of the IT workforce may be constrained by the Army's desire or need to maintain a minimum number of uni-

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[19]Quoted in *Government Computer News,* GCN.com, April 17, 2000, "Army CIO says Bandwidth, Not Personnel, Should be Top Priority."

[20]The Center for Army Analysis conducted a study of historical experiences of contractors in theater operations from 1775 to 1999, in order to develop insights into potential future roles. The study discusses several risks that must be considered when making the decision whether or not to use contractors in a theater of operations. See *SHECITO* (2001).

[21]While there is no clear legal definition for a government corporation, these corporations perform commercial-like activities that serve a public mission. An example is the Corporation for Public Broadcasting. See Hynes (2000).

formed personnel in certain types of support functions. Army end-strength limitations imposed by Congress might also restrict any reconfiguration.

Changing the grade composition of the workforce might be constrained by the absolute need for individuals with seniority and experience, the need to maintain certain ratios of supervisory personnel to subordinates, and the need to ensure that enough senior positions are available to allow the military to satisfy reasonable expectations for career advancement by junior personnel.

The use of nonmilitary labor will be limited because some positions will always be regarded as inherently governmental and because some deployable positions may be inappropriate for civilian personnel. Labor costs and the fact that funding for government civilian and contractor civilian personnel comes from different sources also restrict how much civilian labor can be used and how it can be allocated. Considering the problems the government is having recruiting civilians for government service, the costs of increased pay and bonuses to expand their use could also be significant. These cost restrictions can be complicated by the interplay of *total* Army budget limitations with other limitations on subsets of the Army budget.

Inherent in many of these constraints are considerations of flexibility—both in hiring and in ease of transfer. Once obtained and trained, uniformed Army personnel are easy to transfer to new locations and use in positions different from those they were "hired" to fill. However, it takes time to recruit and train a soldier. Contractors can be hired relatively quickly, but it may be difficult to move them from place to place if requirements change unexpectedly.

MODELING THE PROBLEM

The Army of the future will need to accomplish its IT tasks within the constraints of available personnel and budgets. Doing so may require changing how government personnel are used or increasing the use of contracted personnel. DoD emphasis on strategic manpower management could increase the flexibility to make these changes. In addition to getting the job done, the Army might want to minimize costs, or maximize some other measure of performance.

These requirements together describe a "classic" linear programming problem: to optimize an objective within given constraints.

Similar problems have been addressed in different areas by RAND researchers in the past. Buchanan and Hosek (1983) studied the cost-effectiveness of the Air Force's practice of using physician assistants and medical corpsmen instead of a physician to perform some duties. Linear programming allowed them to explore ways to assign work to physicians, physician assistants, and medical corpsmen in a way that satisfied a base's medical needs at minimum cost.

A RAND study by Palmer and Rydell (1989) examined the concept of managing the "total defense labor force." This study used linear programming to evaluate force mixes that could meet U.S. defense requirements at minimum cost while considering the constraints defined by the relationships between wartime and peacetime roles of civilian and military personnel, the cost-effectiveness of different manpower mixes, and the peacetime surge and sustainment requirements.

More recently, Moore et al. (1996) have developed a complex linear programming approach to modeling interactions among wartime requirements, peacetime basing options, and manpower and personnel policies to determine the mix of personnel and unit types that can meet Air Force contingency needs at minimum cost.

Finally, the Army has used linear programming to study personnel distribution options and develop an implementation plan for the new Army Manning Standard—an effort to improve and sustain manning at high levels (Sweetser et al., 2001). Moreover, the Army's existing strength management system uses linear programming extensively.[22]

A similar framework for analysis can address several issues raised by the constraints the Army faces when determining how to accomplish its IT/IA tasks:

- How does the Army deal with budget constraints?

[22]See Schank et al. (1997).

- If manning is less than 100 percent, what flexibility exists to borrow manpower from other sources?
- If manpower cannot be borrowed, is it acceptable to allow services to be degraded?
- Can we quantify the consequences, in terms of costs and manpower distribution, of policy changes made in response to budget constraints or flexibility issues?
- Does outsourcing save money?

The next chapter describes the framework of such a structure.

Chapter Three

A LINEAR PROGRAMMING MODEL FOR PERSONNEL STAFFING STRATEGIES

Our goal is to develop a model that helps determine the effect of different management policies on workforce composition and personnel costs. To do this, we must represent the workforce, the job requirements, and the personnel policies of a specific installation. A larger, so-called "enterprise" model would consist of several activities or installations competing for resources on a regional or global basis.

In this approach to workforce planning, we assume that people have occupational designations and organizations have jobs to be performed. The problem is to assign people to jobs in a way that optimizes a certain criterion—e.g., minimize total cost. Some basic assumptions used in this model's structure include the following:

- People are differentiated as military, government civilian, or civilian contractors.
- Associated with each person is a skill, an employment cost, and one or more jobs that the person is qualified to perform.
- The supply of some types of people is strictly limited, while the supply of other types can be increased at a cost.
- Each job within an organization can be traced to one of two types of authorizing documents (TDA or TOE).
- An individual can be assigned to one and only one job.
- While all people need not be assigned jobs, all jobs must be filled.

Workforce management policies are implemented by adding (or removing) restrictions on an acceptable personnel assignment solution. A restriction can be added by changing the characteristics of the workforce or the jobs they must fill. Another way to implement a policy is to add a requirement (constraint) that a solution must satisfy. For example, we might stipulate that the total payroll for civilians must not exceed the amount budgeted for salary.

By manipulating workforce and job characteristics and by adding or relaxing constraints, the model can be used to examine the effects of policy changes on such personnel issues as military and civil service representation in jobs authorized by the TDA and job grade/skill requirements. The model can also show the potential cost consequences of these policy changes as well as the implications of increased outsourcing.

THE MATHEMATICAL FORMULATION

To define the model's structure, several indices, parameters, and variables must be defined.

Indices

We introduce the following notation to describe the possible personnel sources, jobs, organizations, and authorization documents:

I the index set of personnel,

J the index set of jobs,

K the index set of organizations, and

L the index set of authorization documents.

In addition to these primary index sets, we use some derived index sets for convenience:

I^a the subset of personnel in set I who are active-duty military;

I^{CS} the subset of personnel in set I who are civil service employees; we will assume that $I^A \cap I^{CS} = \varnothing$—that is, that no one is both active-duty military and a civil servant at the same time; and

A^O a subset of the Cartesian cross of sets I, J, K, and L that defines the assignment possibilities for individuals. The 4-tuple (i,j,k,l) is an element of A^O if person i is allowed to be assigned to job j in organization k by authorization document l.

Parameters

The given data for the installation are defined by the following parameters:

INV_i the maximum number of people of type i available for assignment;

P_i the penalty paid per unit violation of the INV_i limit;

C_i the weekly cost of each person of type i employed;

RQ_{jkl} the number of jobs j authorized in organization k by document l;

SRQ_{jkl} the number of additional (shadow) job slots j required in organization k but not authorized by document l;[1]

G_{jkl} the minimum fraction of the workforce performing job j in organization k by document l required to be civil service personnel; and

M_{jkl} the minimum fraction of the workforce performing job j in organization k by document l required to be military personnel.

Variables

The variables or unknown values are as follows:

X_{ijkl} the number of personnel i assigned to perform job j in organization k under document l, and

[1]This is meant to capture the idea that shadow work detracts from the performance of a person's assigned duties and that new positions for the work are needed.

Z_i the number of additional personnel of type *i* assigned in excess of INV_i.

Using the indices, parameters, and variables above, a set of objective functions and constraints are defined.

Objective Functions

A number of objectives could be desired, depending on the goal of the policymaker in a given situation. The function given in (3.1) would be used to determine the assignment of people to jobs that results in the minimum cost.

$$\sum_{(i,j,k,l)\in A^0} C_i X_{ijkl} + \sum_{i\in I} P_i Z_i \tag{3.1}$$

The first term sums the cost incurred, C_i, when person *i* is assigned to job *j* in organization *k* under authorization document *l*. The second term accounts for the additional cost or penalty paid each time someone new must be added to the original workforce to meet changed requirements.[2]

On the other hand, a policymaker might have the objective of maximizing the number of government employees hired. This would include personnel in the active-duty military and government civilian employees. The objective function for this is shown in (3.2),

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[2]It is appropriate at this point to comment on the use of penalty coefficients and how values for these coefficients may be determined. Penalties are used as a means of making trade-offs between incompatible or unattainable requirements. In general, penalty coefficients are assigned to the surplus and/or slack variables of a constraint for one of two purposes: to establish the relative importance of one constraint to another or to represent the marginal cost of obtaining or failing to consume a unit of resource. Although easy to implement in algebra and in a computational form, the challenge is to select valid values for the penalties. One approach is to solve the problem without the use of deviation variables (e.g., Z_i) and use the dual variables of the rigid constraints as initial values. An alternative is to choose an appropriate cost based on an understanding of the problem. We chose to use an amortized life-cycle cost for each personnel type *i* when we employed a marginal cost interpretation of P_i. In other cases, some P_i were made very large relative to others to make violation of a particular constraint, or set of constraints, less desirable.

which simply adds up the number of personnel of each type that are assigned to IT jobs.

$$\sum_{i \in I^A \cup I^{CS}} \sum_j \sum_k \sum_l X_{ijkl} \tag{3.2}$$

Constraints

As with the objective function, a variety of constraints can be imposed. The following six constraints are typical.

$$\sum_{j \in J} \sum_{k \in K} \sum_{l \in L} X_{ijkl} \le INV_i + Z_i, \; i \in I \tag{3.3}$$

$$\sum_{i \in I} X_{ijkl} = RQ_{jkl} + SRQ_{jkl}, \; j \in J, \; k \in K, \; l \in L \tag{3.4}$$

$$\sum_{i \in I^A} X_{ijkl} \ge M_{jkl} \sum_{i \in I} X_{ijkl}, \; j \in J, \; k \in K, \; l \in L \tag{3.5}$$

$$\sum_{i \in I^{CS}} X_{ijkl} \ge G_{jkl} \sum_{i \in I} X_{ijkl}, \; j \in J, \; k \in K, \; l \in L \tag{3.6}$$

$$\sum_{i \in I^{CS}} \sum_{j \in J} \sum_{k \in K} \sum_{l \in L} C_i X_{ijkl} \le \sum_{i \in I^{CS}} C_i INV_i \tag{3.7}$$

$$X_{ijkl}, \; Z_i \ge 0 \tag{3.8}$$

The constraints in (3.3) ensure that the number of people of a particular kind assigned to all job openings does not exceed the available inventory. The appearance of the decision variable Z_i on the right-hand side of the inequality allows additional inventory to be procured. However, this additional inventory comes at a price P_i. The P_i term is included in the cost objective function (3.1). In practice, when the goal is to minimize cost but also recognize that some inventories are limited, P_i is set very high. This allows the model to "hire" extra personnel but only if absolutely necessary, and it helps the analyst determine the consequences of limited inventories.

The constraints described by (3.4) ensure that enough people are assigned to meet the authorized and unauthorized job requirements in each organization. Taken together, constraints (3.3) and (3.4) define the solution space for a general class of linear programming models known as network flow problems.

Constraints (3.5) and (3.6) guarantee that a minimum proportion of specific jobs in an organization are performed by military personnel or civil service personnel, respectively.

If payroll constraints exist, the constraints of (3.7) would be used. As defined in this example, the constraint requires that the total compensation paid to an alternative civil service workforce must not exceed what is currently paid to the existing civil service workforce. Finally, the constraints defined by (3.8) ensure that solutions are nonnegative.

DATA REQUIREMENTS

To apply this model to the Army-wide IT/IA workforce, we could address four "archetype" installations that would allow consideration of four fundamental missions of Army organizations:

- Force projection installations.
- Training installations.
- Depot, arsenal, or laboratory installations.
- Headquarters installations.

Analyzing any of these archetypes would require the collection of four categories of data: the number of people available from each personnel source, the number of positions that must be filled (or how much work needs to be done), the salaries of individuals in different personnel categories, and existing limits for assignments of different personnel to different jobs. Specific data needs can be broken down as follows:

Military Personnel

- Current active-duty inventory by MOS and skill level.
- Amortized weekly life-cycle costs per MOS and skill level (perhaps including MOS-specific training).
- Aggregate total of personnel, by TOE and TDA at MOS/skill level in the following categories:
  - personnel required,
  - personnel authorized,
  - number of positions filled,
  - number of positions filled plus an estimate of the size of the shadow workforce, and
  - number of positions filled plus an estimate of the size of the shadow workforce extrapolated for objective force.

Civil Service Personnel

- Current Army inventory by civilian personnel career field and grade level.
- Average weekly costs (perhaps to include career field–specific training).
- Equivalences with MOS/skill level positions at the installation level.
- Aggregate total of personnel by TDA at career field/grade level, of the following categories:
  - personnel required,
  - personnel authorized,
  - number of positions filled,
  - number of positions filled plus an estimate of the size of the shadow workforce, and

— number of positions filled plus an estimate of the size of the shadow workforce extrapolated for objective force.

Contractor Personnel

- Private-sector inventory in jobs equivalent to civilian personnel career fields and grade levels.
- Average weekly costs at the installation level.
- Number of personnel working by activity-type at an equivalent GS career field/grade level.

MAKING THE MODELING PROBLEM MANAGEABLE

Examination of the data available from the project sponsor and the Army Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) left a number of questions unanswered. For example, despite the BAHR survey's finding that the shadow workforce was performing approximately 25 percent of IT/IA functions, limited information was discovered about who was performing the work and there was practically no discussion of why the percentage of shadow work was so high. Personnel data also indicated a higher-than-normal turnover rate among IT/IA government civilian employees, yet the average age of the work force had continued to increase over the years.

We also noted that the TDA data from the POSCO (position code) file for the Army overall included what to us appeared to be an unusually large number of relatively junior enlisted personnel, whereas we had expected that virtually all junior IT/IA military personnel slots would have been in the TOE portion of the Army. We suspected that this was the result of military personnel being a "free" resource at the installation level but were unable to locate information confirming this.[3]

[3]"Free" in this instance means that military personnel pay and benefits are not part of an installation budget, whereas civilian employees and contract costs must be funded by the installation. Hence, a TDA organization can be larger for a given budget at the installation level if it includes military personnel in lieu of civilian employees.

While we were attempting to address the data anomalies, we also realized that the initial efforts with the personnel model must be limited in scope. The number of personnel Army-wide and the wide variation in occupations would make it impossible to evaluate the results of test runs during development. Accordingly, we began to address the best way both to increase our understanding of the available data and to locate a suitable installation that had a sufficient number of activities to test the model and that we could visit and understand.

Chapter Four

FORT BRAGG AS A TEST CASE

To learn more about personnel involved in IT functions and to discuss model development, we wanted to visit an Army installation that

- has a relatively large population of IT/IA personnel,
- comprises a good mix of deployable units,
- requires IT/IA activity in its deployed units,[1]
- requires units left behind during deployment to be involved in the support of deployed units,[2]
- possesses a relatively constant population mix,[3] and
- is easily accessible.

After discussions with U.S. Army Combined Arms Support Command (CASCOM), these criteria led us to focus on Fort Bragg. This installation not only has a large population and an excellent mix of units, but

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[1]A mix of deployable units and installation units that would support them would allow us to estimate, albeit crudely, the effect of deployment on the workload of both deployed and stay-behind units. This suggested Fort Lee, Fort Bragg, and Fort Hood as possible candidates for study.

[2]Fort Lee was eliminated as a potential test case because little IT/IA activity takes place in its deployed units and the installation is not very involved in the support of deployed units.

[3]This criterion eliminated Fort Hood. Because a great deal of the IT/IA activity at Fort Hood is related to the test and evaluation of systems related to the Army's digitization, the number of people performing IT/IA functions and the mix of military, civilian, and contractor personnel is constantly changing.

also is involved with other installations containing XVIII Airborne Corps subordinate units. The organizational levels at Fort Bragg include XVIII Corps, the 82nd Airborne Division, Womack Army Medical Center, and garrison personnel.

DATA OBTAINED FROM FORT BRAGG

We visited Fort Bragg in June 2001 and met with the Corps G1, G6, and G7 as well as with the various garrison support activities.[4] In our discussions, we found that officer, warrant officer, enlisted, and government civilian personnel were assigned to a variety of IT positions. Potential military assignments appear in Table 4.1.

Determining the authorized number of military personnel in TOE and TDA positions was straightforward, and this information is broken down by MOS and rank in Table 4.2.[5] However, because the gar-

Table 4.1

IT Positions Available at Fort Bragg

Personnel Category	Positions
Officer	Senior Automated Systems Management Officer Automated Systems Management Officer Information Management Officer
Warrant Officer	Senior Data-Processing Technician Data-Processing Technician
Enlisted	Software Analyst Information Systems Operator Senior Local Area Network Manager Senior Software Analyst Senior Information Systems Operator Global Command and Control System (GCCS) Analyst Information Systems Team Chief Software Analyst Team Chief Supervisor, Software Analyst Supervisor, Information Systems

[4]G1 is the organization responsible for personnel, G6 for communications, and G7 for long-term planning.

[5]This is based on an extract form the Army's Position Code (POSCO) file.

rison is in a continuing process of conducting A76 competitions for the possible outsourcing of various activities, there were some limitations on the details organizations were willing to provide us in other areas. In particular, we were only given the *total* number of civilians engaged in TDA functions.[6] Table 4.2 uses this total figure and assumes that the distribution of civilian personnel mirrors the Army-wide distribution.[7]

Table 4.2

IT Authorizations at Fort Bragg

MOS/Occupational Code	Rank/ Grade	TOE	TDA	Combined
74B10	E1–E4	76	5	81
74B20	E5	23	2	25
74B30	E6	12	2	14
74B40	E7–E8	8	2	10
251A	W2	2		2
251A	W3	1		1
251A	W4	5		5
53A	O3	1		1
53A	O4	7		7
53A	O5	4		4
GS334	GS7		3	3
GS334	GS9		37	37
GS334	GS11		33	33
GS334	GS12		33	33
GS334	GS13		2	2
Military Total		139	11	150
Civilian Total		0	108	108
Grand Total		139	119	258

NOTE: Because of the A76 study, Fort Bragg would only provide the *total* number of civilians. The civilian distribution in this table is based on the assumption that Fort Bragg's distribution mirrors the Army-wide distribution for GS334 personnel.

[6]Those we interviewed treated the grade distribution as sensitive information because details about the distribution of civilian workers could be used by contractors participating in the A-76 competition to structure their workforce to be more competitive in price than the government organization currently accomplishing the work.

[7]The GS-0334 Computer Specialist Series is being absorbed into the new Information Technology Management Series, GS-2210. Forecasts for future requirements discussed in Chapter One referred to requirements for civilians in the GS-2210 series.

INSIGHTS FROM THE INTERVIEWS

Although we were somewhat frustrated by the limitations on detailed information that existed because of the A76 study, the study's conduct also helped us gain some unexpected insights into IT/IA personnel issues.

Military Personnel in TDA Activities

Very few military personnel engage in garrison activities at Fort Bragg. This is because, although it is true for budgetary reasons that military personnel are desirable for such work, the A76 costing rules make them undesirable. When developing the most efficient organization (MEO) for a government activity subject to A76 competition, military personnel benefits make them actually more expensive than government civilian employees of comparable skill.[8] Accordingly, Fort Bragg has eliminated as many military positions in its TDA activities as possible. In most of the business centers, only the officer in charge is military. It seems likely that this beneficial effect will spread throughout the Army, keeping military personnel out of garrison activities and therefore available to TOE units.

Government Civilian Workforce

As we had expected, available funds drive the number of personnel in the TDA activities. However, officials we interviewed emphasized that a considerable amount of flexibility exists in the use of those funds in that a vacant high-grade position can be converted to two lower grade positions or vice versa.

In addition, hiring at Fort Bragg has led to a civilian workforce that stays relatively old, despite turnover. This is because a major recruiting pool for government civilian positions is the retired military population in the area. Thus, a new worker may be as old as, or older than, the person being replaced.

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[8]Gates and Robbert (1998) performed a detailed comparison of the costs of military and civil service personnel. They concluded (p. 63) that replacing military personnel with civilians can produce cost savings under many, but not all, circumstances. Their military costs included recruiting and training costs.

Shadow Workforce

This issue turned out to be more complex than we had anticipated. Although we had expected to find that some personnel were doing IT work outside their assigned positions because of limited authorizations or budget constraints, we also found a third reason for shadow workers that is, on reflection, understandable but will complicate the question into the indefinite future. What we found is also consistent with the findings of the Human Resources Integrated Process Team *Final Report* (1999) mentioned in Chapter Two. Shadow workforce requirements result from three causes: lack of authorizations, budget constraints, and multiskill positions.

Lack of Authorizations to Support a Requirement. The Army has been expanding its use of computer systems in administrative applications at a rate that has not been matched by either requirements documents or by personnel availability. The Personnel Support Group at Fort Bragg has nearly 500 computers of various types, but the headquarters is not authorized any officers to manage the resulting networks. Officers with other specialties are hence designated for the job. This practice has its own risks. The G6 has provided training in network administration only to find that the officers so trained are very attractive to industry and that the Army cannot compete to retain their services. This type of shortage being filled by shadow workers will likely always exist to some extent, given the difficulty of recruiting and retaining specialists in the IT field.

Budget-Driven Constraints. Fort Bragg has a communication activity called the Red Switch that allows units to communicate in a variety of modes, including secure voice and data. This is not a deployable function, and everyone seemed to agree that it is a natural activity to be supported by the installation either with government civilian employees or contractors. However, funds are not available for either. The 35th Signal Brigade therefore supports the switch, but this brigade is a deployable XVIII Airborne Corps unit. The solution to this type of shadow force is readily apparent, but it will always be tempting to use personnel from tactical units where possible to alleviate budget shortfalls on the installation. It is also a reasonable solution under some circumstances if managed properly because deployments involving the entire corps are extremely rare.

Multiskill Positions. Many jobs require not only computer-related skills but also considerable knowledge of a specialized field, such as finance or supply. In many of these cases, it is considered more effective to provide network-related training to qualified specialists than to acquire IT specialists and teach them the functional area. This class of personnel requires some skill identifier to avoid confusion, as this group will grow considerably in the future. Elements of the ABCS, such as the Combat Service Support Control System (CSSCS) and the All-Source Analysis System (ASAS), are to be operated by non-IT personnel, but the IT-related aspects of the job will not be outside of the skill base of the position. Therefore, such positions should not be considered a part of the shadow force.

Contractors

Fort Bragg is not currently using individually contracted IT employees or contracted IT services.

PERSONNEL COSTS FOR MODELING PURPOSES

One purpose of the modeling effort for this project is to assess the relative cost of alternative approaches to fill required positions. Hence, it is important that the cost to fill a position be consistent among military personnel, government civilian personnel, and contract personnel. Direct labor costs are readily available for military and government civilian personnel. However, within each grade there is considerable variation based on longevity. Contractors generally do not disclose in detail the process for determining individual pay levels. Perhaps of even more importance, major differences exist among the three classes of personnel in the determination of indirect and overhead costs. Additionally, even when a position or an activity is converted to contract, a cost to the government remains in that the contract must be administered. We expected to have to develop our own system for addressing fully burdened personnel costs. However, the A76 Costing Manual (2001) and the Army Military-Civilian Cost System (AMCOS) resolved the dilemma.

The A76 Costing Manual is published to guide the evaluation of competitive bids between government entities and contractors for the performance of government activities. Thus, it provides authoritative guidance on precisely the type of comparison that concerns us.

The U.S. Army Cost and Economic Analysis Center (USACEAC) is responsible for implementing the Army Cost and Economic Analysis Program. It develops cost and economic analysis policy and makes available cost estimating models and cost databases for Army-wide use. AMCOS is a user-friendly PC-based software package that provides military and civilian cost estimates for acquisition, installation, operations, force/unit costing, and a variety of cost analysis requirements. USACEAC operates, maintains, updates, and modifies the AMCOS database.[9]

Government Civilians and Military Personnel

AMCOS contains cost data for military and civilian personnel by grade and occupation and can provide users with cost details by MOS and budget appropriation for any unit configuration. We used the AMCOS software to obtain costs for both military and civilian personnel by grade and occupational specialty.

Table 4.3 summarizes the cost information for military and government civilian IT workers.[10]

Contract Administration Costs

The A76 Costing Manual specifies the allowable contract administration cost in terms of the number of government administrative personnel authorized for given numbers of employees under the contract. However, the authorization is specified for ranges of contractor personnel, resulting in considerable variation in the administration cost per employee. For a contract with 21 employees, two government personnel are authorized, which would result in administration cost of $4,300 per contract employee per year. However, for

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[9]USACEAC has a Web site (www.ceac.army.mil) that includes access to AMCOS.

[10]The military costs are amortized life-cycle costs but do not include recruiting and training costs.

Table 4.3

Weekly Costs for Government Employees (in Dollars)

Type	Rank/Grade[a]	Weekly Cost
Enlisted	74B10	704
	74B20	825
	74B30	969
	74B40	1,148
Warrant Officer	W1	1,075
	W2	1,232
	W3	1,456
	W4	1,777
Officer	O3	1,525
	O4	1,844
	O5	2,187
Government Civilian	GS3	558
	GS5	752
	GS6	836
	GS7	846
	GS9	1,032
	GS11	1,247
	GS12	1,528
	GS13	1,821

[a]Military employees are listed by rank; government civilians are listed by grade.

50 contract employees the same two government personnel are authorized resulting in a cost of $2,600 per employee per year. Similar variation exists for larger and smaller contracts. We opted to use a midrange figure of $3,200 per employee per year that was added to the direct and indirect costs calculated below.[11]

Contract Labor and Overhead

According to U.S. Office of Personnel Management documents, the duties of civilians in the GS-0334 career field include "analyzing, managing, supervising, or performing work necessary to plan, design, develop, acquire, document, test, implement, integrate,

[11]Before making a decision, of course, the sensitivity of model results to changes in this value would have to be examined.

maintain, or modify systems for solving problems or accomplishing work processes by using computers."[12] To use the linear programming model to assess the potential costs of outsourcing IT positions, we must first determine the salaries of people who perform similar functions in civilian occupations.

Because Fort Bragg does not use contractors for IT services, we could not obtain data on actual cost. Instead, we used the Current Population Survey (CPS), a nationally representative survey of all workers. The Bureau of the Census conducts it monthly for the Bureau of Labor Statistics, and the survey structure allows us to categorize workers by their occupations and experience. We created two groupings of occupations in the CPS data that relate closely to the GS-0334 computer specialist: an IT core group and an IT-related group. The IT core group is made up of workers who develop or maintain computer systems that solve problems; the IT-related group uses computers or computer systems to accomplish their work. Table 4.4 shows a complete list of the CPS occupations for each group.

We then defined three experience categories as follows: junior (a bachelor's degree and maximum five years experience), midlevel (bachelor's, master's, or professional degree, or six to 15 years experience), and senior level (15 years or more experience).[13]

We determined weekly contract labor costs using a two-step procedure. First we used the CPS to determine the base wages for IT workers in North Carolina. Second, we burdened these wages using customary fringe benefit and overhead costs for these industries. We used data on workers between the ages of 21 and 64 from the March

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[12]From an OPM document titled, Computer Specialist Series, GS-0334, July 1991, TS-106. This is available on the Internet at http://www.opm.gov/fedclass/gs0334.pdf. As noted earlier, the GS-0334 series is being redesignated the GS-2210 series. OPM's August 2001 Handbook of *Occupational Groups and Families*, says that GS-2210 covers "only those positions for which the paramount requirement is knowledge of IT principles, concepts, and methods. [IT] includes computers, network components, peripheral equipment, software, firmware, services, and related resources."

[13]Using age as a measure of experience is more reliable in many respects because workers often inflate their experience level or confuse experience in their current positions with total experience.

Table 4.4

IT Occupation Classifications in the CPS

IT Core	IT-Related
Job Title (CPS Code)	Job Title (CPS Code)
Computer Scientists (64) Computer Science Teachers (129) Computer Programmers (229) Tool Programmers, Numerical Control (233) Electrical and Electronic Technicians (213) Operations and Systems Researchers and Analysts (65)	Statisticians (67) Natural and Mathematical Scientists ([69 & 74], 68) Engineers, Architects, Surveyors, and Drafting Occupations (43, 44, 45, 46, 47, 48, 49, 53, 54, 55, 56, 57, 58, 59, 63, 218) Electricians (575, 576, 577) Electrical and Electronic Equipment Repairers (523, 525, 526, 527, 529, 533) Actuaries, Accountants, and Auditors (66, 23) Financial Managers and Management Analysts (7, 26) Financial Records Processing Occupations (337) Supervisors, Distribution, Scheduling, and Adjusting Clerks (307) Air Traffic Controllers (227)
Supervisors Financial Record Processing (304) Computer Equipment Operator (305)	Technicians Engineering (214, 215, 216) Surveying and Mapping (218)
Operators Broadcast Equipment (228) Computer (308) Peripheral Equipment (309)	Officers Chief Communications (306) Other Financial (25) Operators Billing, Posting, and Calculating Machine (344), Numerical Control Machine (714) Communications Equipment (348, 353)

SOURCE: The CPS (available at http://www.bls.census.gov/cps/bocccd.htm).

1999 Supplement to predict average weekly wages for workers who live in North Carolina.

We estimated a linear regression model to determine an upper bound on the predicted average weekly wages for white male workers who live in North Carolina.[14] Next, we burdened the wages for fringe benefits (46 percent of wages) paid by the employer (Social Security, Medicare, health and disability insurance, vacation, and retirement) and off-site overhead (31 percent) and profit (8 percent).[15] Table 4.5 presents estimates for weekly contract costs for IT core, IT-related, and non-IT workers by education and experience level.

We also investigated the charges from commercial firms that provide IT services. We contacted some well-known national firms as well as other local and national firms with Web sites. The responses we received are given below in Table 4.6. This is not a statistically reliable investigation, but it does suggest our estimates for entry and midlevel core and IT-related costs are consistent with anecdotal evidence. Our regressions suggest that a contractor may charge from $1,675 to $1,834 per week for a junior-level consultant. At National Firm Number One, a consultant who requires supervision would cost

Table 4.5

Average Weekly Contract Cost Estimates[a]

	Occupation Category		
Experience Level	Core IT	IT-Related	Non-IT
Entry	$1,834	$1,675	$1,368
Midlevel	$2,254	$2,095	$1,788
Senior	$2,318	$2,159	$1,852

[a]This burden assumes 46 percent in fringe benefits, 31 percent for off-site overhead, and an 8 percent fee.

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[14]We used a linear regression model to predict average weekly wages for all workers in the 1999 CPS. The resulting equation was:

W_i = 27.90 + 86.9*(Male) + 63*(White) + 210*(IT) + 138*(IT-Related) + 295*(Senior Level) + 267*(Midcareer) + 77*(Entry) – 31*(North Carolina) + 482*(Full Time). This simple model performed well: the adjusted R-square was 0.377 and all variables were statistically significant at the 5 percent level or better. We inflated our predicted values for white male workers in North Carolina to 2001 dollars using the Consumer Price Index.

[15]These rates are nominal values based on interviews with well-known commercial firms that offer IT services.

Table 4.6

Weekly Rates for IT Providers in 2001

Vendor	Junior	Midlevel	Senior	Average
National Firm Number One	$1,600	$2,400	$3,200	
National Firm Number Two				$3,800
National Firm Number Three				$1,200
Anonymous Vendor, North Carolina		$2,600	$3,800	

SOURCE: Telephone interviews with IT service providers.

NOTE: This table assumes a 40-hour work week. A junior-level IT provider works with supervision; a midlevel provider works with limited supervision; and a senior-level provider works independently and has extensive knowledge. For the anonymous vendor, an equivalent midlevel consultant would be an A+ certified technician with an associate's degree in computer science and a senior consultant would be a Novell-certified technician with a bachelor of science degree in engineering technology.

an average of $1,600 per week. Our estimates for senior core and IT-related occupations are below the spot market quotes. This could be because we computed overhead and fee at the same rate for workers at all experience levels. Our investigations also showed that many types of contractual arrangements are available. In particular, many of these arrangements have nonlinear manpower charges.

SUMMARY

Table 4.1 lists the IT positions available to military personnel at Fort Bragg. Using the linear programming model to analyze the costs of alternative personnel policies requires a determination of the potential assignments of government civilians to military positions and other assignments available to government civilian and contractor personnel. Potential use of government civilians suggested by the civilian personnel office at Fort Bragg, the cost information for government civilians and contractors, and the division of contractors into junior-, mid-, and senior-level categories makes the potential assignments in Table 4.7 reasonable.

Whether these assignments are allowed, of course, is determined by policy decisions and constraints. The effects of these decisions are what we can now test.

Table 4.7

Possible Assignments for Government Civilians and Contractors

Grade	Occupation	Position
GS13	CP334	Automated Systems Management Officer
GS12	CP334	Senior Data-Processing Technician
GS11	CP334	Senior Data-Processing Technician
GS9	CP334	Data-Processing Technician
		Software Analyst Supervisor
		Information Systems Supervisor
GS7	CP334	Software Analysis Team Chief
		Information Systems Team Chief
GS6	CP334	Information Systems Senior Operator
		Senior Software Analyst
GS5	CP334	Information Systems Operator
		Software Analyst
GS3	CP334	Information Systems Operator
Contractor		
Senior-Level		Positions filled by GS13
Midlevel		Positions filled by GS11 and GS12
Junior-Level		Positions filled by GS6 and GS9

Chapter Five

RESULTS

This chapter shows how the model can assist in the analysis of different policy situations. We consider three problems:

- Estimating the costs of the shadow workforce.
- Estimating the costs of the increased workload expected because of the introduction of ABCS.
- Analyzing the consequences of different approaches to dealing with personnel restrictions—specifically, a 90 percent fill rate for authorized positions.

The "base case" for all scenarios is the composition of the IT workforce at Fort Bragg that we developed based on our interviews and the POSCO file. Table 4.2 showed the distribution of personnel by occupational code and rank and grade. Because comparing model outputs is easier with graphical displays, Figure 5.1 shows the Fort Bragg base case distribution by TOE and TDA as a bar chart.

As noted in Chapter Four, no government civilians were in the TOE force. Only 11 military personnel were in the TDA group, and no contractors were performing IT functions in either group. Using the pay figures discussed in Chapter Four, the weekly cost of the base case force is $275,000.

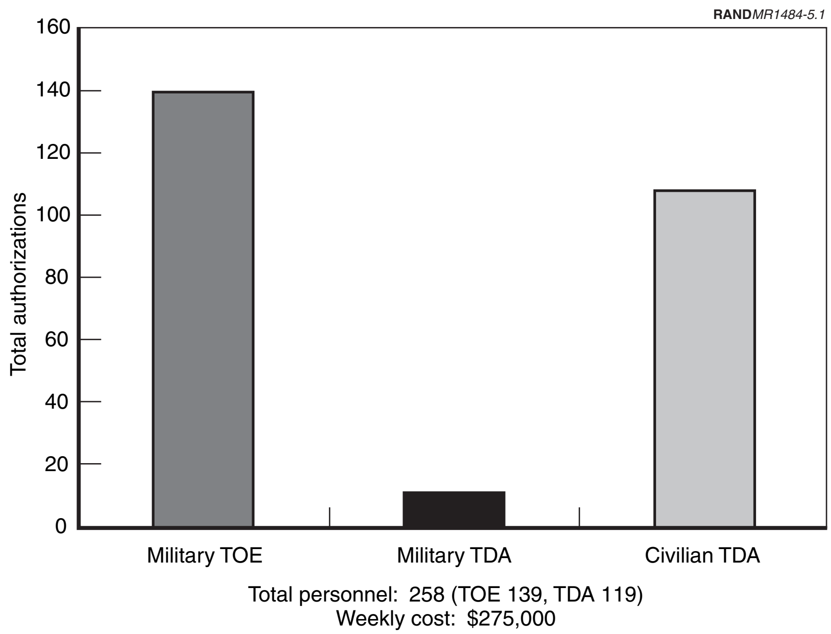

Figure 5.1—Distribution of IT Personnel at Fort Bragg

ESTIMATING THE HIDDEN COSTS OF THE SHADOW WORKFORCE

This scenario is based on the current authorizations at Fort Bragg and assumes that, as the BAHR workforce found, about 26 percent of IT/IA work is accomplished by the shadow workforce. For this case, the model simply increases the required work by 26 percent. Figure 5.2 shows the effect on inventory, which would increase the total personnel required from 258 to 327 (151 TOE and 176 TDA). Figure 5.3 shows weekly costs of the workforce when the shadow workforce is included increase from $275,000 to $347,000.

The increase in inventory and costs gives an idea of the effective number of personnel who are working outside their assigned areas, as well as an indication of the “hidden” cost of the effort that individuals are expending on work outside their specialty area.

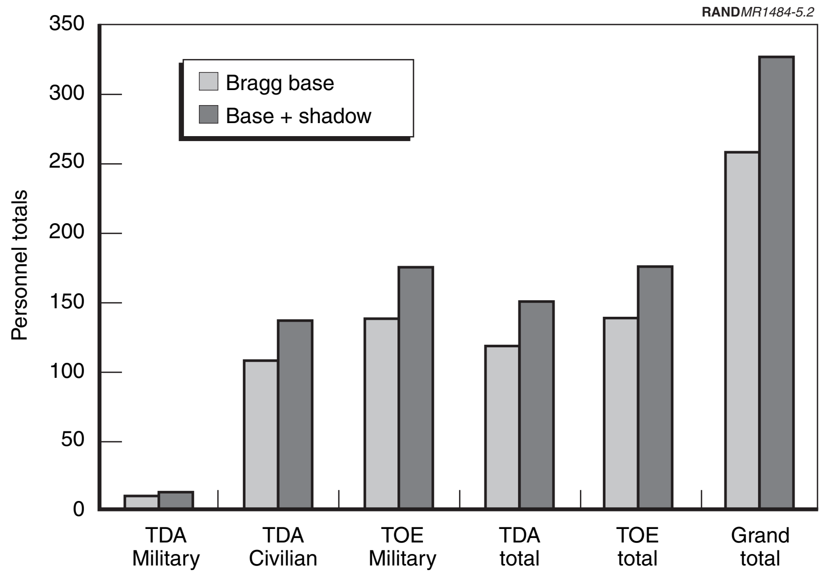

Figure 5.2—Effective Size of the Shadow Workforce

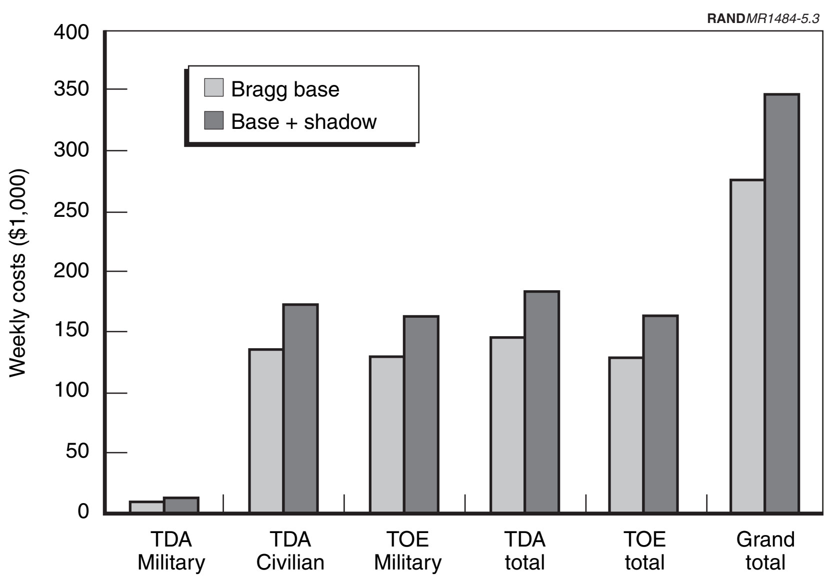

Figure 5.3—Estimating Shadow Workforce Costs

This is not a challenging use of the model. Such a simple assumption for the shadow workforce could easily be worked out by hand or in a spreadsheet. However, if the shadow workforce were recognized to have different effects in different organizations, the model could be used to study different personnel assignment rules that might lower the total costs (including hidden costs) to the organizations.

Estimating the Effects of Introducing ABCS

In this example, the shadow workforce is included in the TDA workforce only. For the TOE workforce, estimates of increases in personnel needs were made based on the November 2000 Force Design Update.[1] Figure 5.4 compares the size of the larger workforce with the current workforce at Fort Bragg.

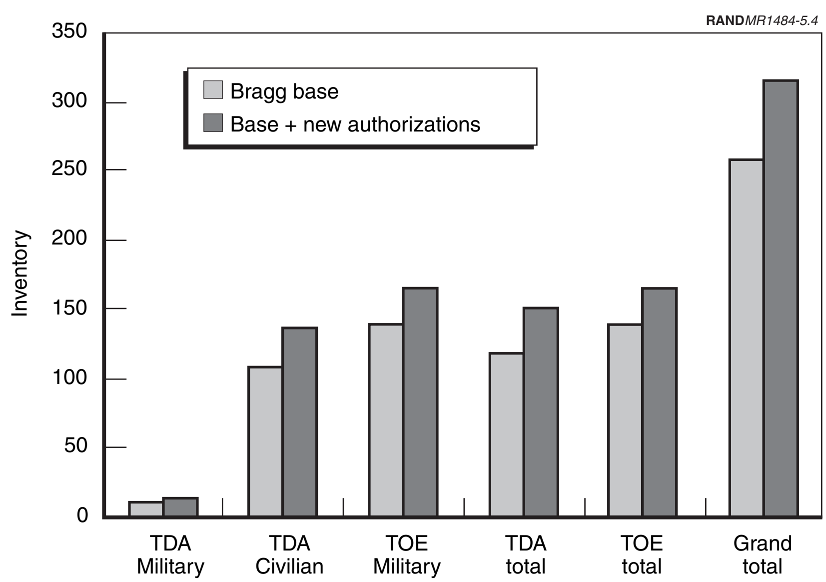

Figure 5.4—Inventory Increases from ABCS Workload

[1]TOE increases used for this scenario were as follows: W2 from 2 to 4, W3 from 1 to 4, O4 from 7 to 11, 74B10 from 76 to 78, 74B20 from 23 to 24, 74B30 from 12 to 20, and 74B40 from 8 to 14.

The total workforce has increased from 258 to 316, with an 18 percent increase in the TOE force (from 139 to 158) and the same 26 percent increase in the TDA force as in the last case. Figure 5.5 shows the increased cost of the larger workforce: the total weekly cost of the new workforce has increased by 25 percent, from $275,000 to $374,000.

Once again, this case does not require a linear programming model. These increases are easily calculated by hand. However, by using the increased workload as a new baseline case, we can use the model to analyze different approaches to meeting the new IT requirements.

INCREASED WORKLOAD: DIFFERENT CONSTRAINTS

It is not uncommon for military units to have vacancies in authorized positions. In fact, the Army sometimes has a *goal* of filling something

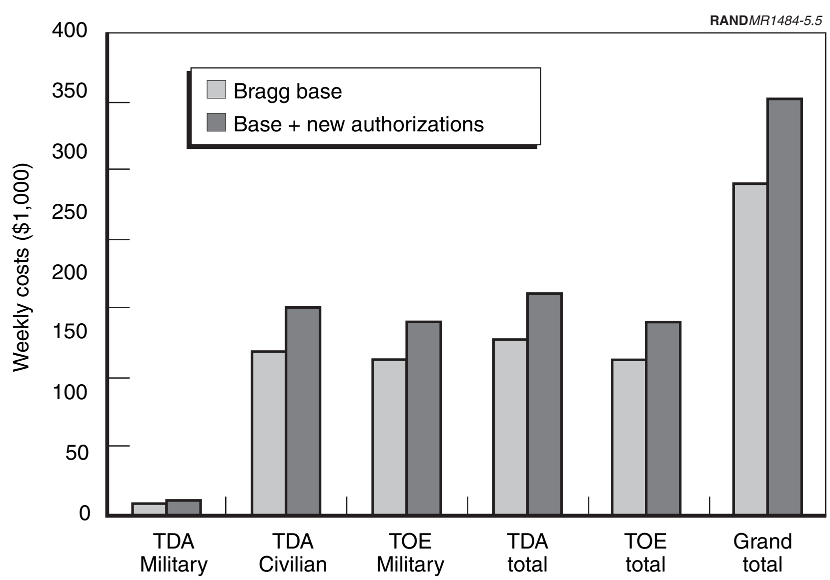

Figure 5.5—Cost Increases with ABCS Workload

less than 100 percent of the authorizations in some units when overall personnel shortages require making choices about where manpower requirements are most critical.

We assume that the Army recognizes the number of authorizations required for the increased demands of ABCS but decides that only 90 percent of the combined TOE/TDA authorizations for military personnel will be filled. We also assume that a unit might make the following decisions in determining how to best fill critical positions in this situation:

- For TOE:
  - Fill the 82nd Airborne Division to 100 percent because it is a fully deployable unit.
  - Fill the enlisted force in the XVIII Airborne Corps to 80 percent, with the remaining positions filled with government civilian personnel.
- For TDA:
  - Eliminate military personnel from TDA positions.
  - Meet TDA requirements (both civilian and military) with the remaining government civilian workforce supplemented by contractors.

With these assumptions, we consider two scenarios in which a decisionmaker faces different constraints:

Scenario 1: The IT requirements must be met without exceeding current government civilian hiring levels. That is, if there are currently 12 GS6 personnel, no more than 12 can be used when workforce assignments are adjusted. However, it is not necessary to use 12 if the work can be accomplished with fewer.

Scenario 2: The IT requirements must be met without exceeding the current total government civilian payroll. In this case, the personnel decisionmaker can manipulate the government civilian workforce as desired, so long as the payroll limit is satisfied.

In both cases, the goal of the unit is to accomplish all of its IT requirements at minimum cost. The model also allows government civilians in grades GS3, GS5 and GS6 to fill appropriate positions (recall that in the base case, Fort Bragg does not have civilians in these grades).

Figure 5.6 shows the inventory differences of the two scenarios from the “base” increased workload case. Bars above zero indicate a larger inventory; bars below indicate a smaller one. We see that both new scenarios have eliminated military TDA personnel, as required. In both scenarios, contractor personnel have been hired for TDA work, with the second scenario (GS pay cap) hiring slightly fewer. The number of TDA civilians is lower in both scenarios than in the base case, but the number of civilians under the pay limit is slightly higher. The number of TOE military personnel has declined and is

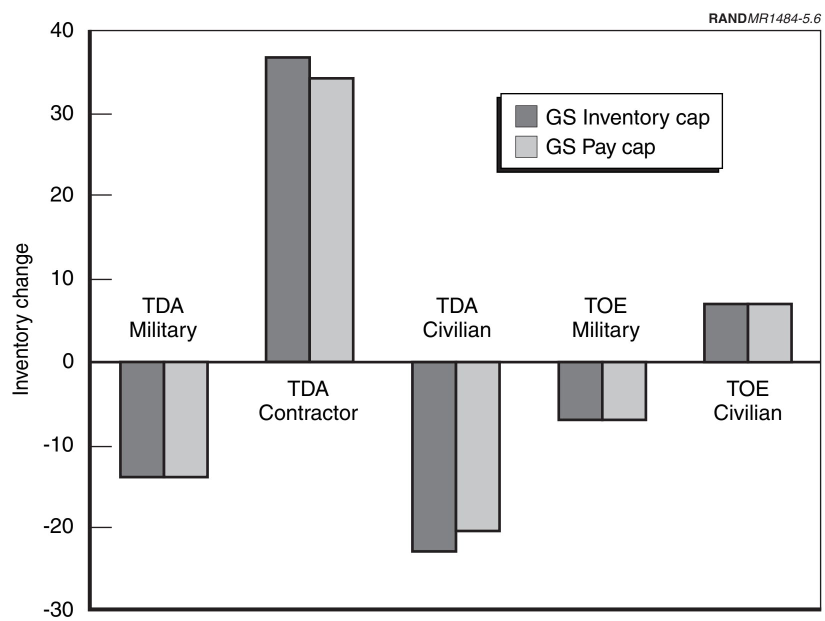

Figure 5.6—Effect of Different Constraints on Increased Workload Inventories

the same in both cases, and the number of newly allowed TOE civilians introduced in both scenarios is the same. Figure 5.7 shows the effects of the different approaches on costs.

The cost comparisons are more interesting than the total inventory comparisons. For one thing, notice that, although Figure 5.6 showed both scenarios hiring the same number of TOE civilians, the cost for these civilians is slightly less under the scenario with the pay cap. Total costs for both scenarios are greater than the base case. This result is consistent with the general principle that if constraints are added to a linear programming problem, the new solution can, at best, be only as good as the old one and will probably be worse. What is a little surprising initially is that the scenario with the pay cap is slightly cheaper (about $6,700 per week) than the inventory limit scenario. At first glance, the "salary cap" scenario might seem more restrictive than the "inventory limit" scenario, and one might expect it to be *more* expensive overall because the model would be forced to

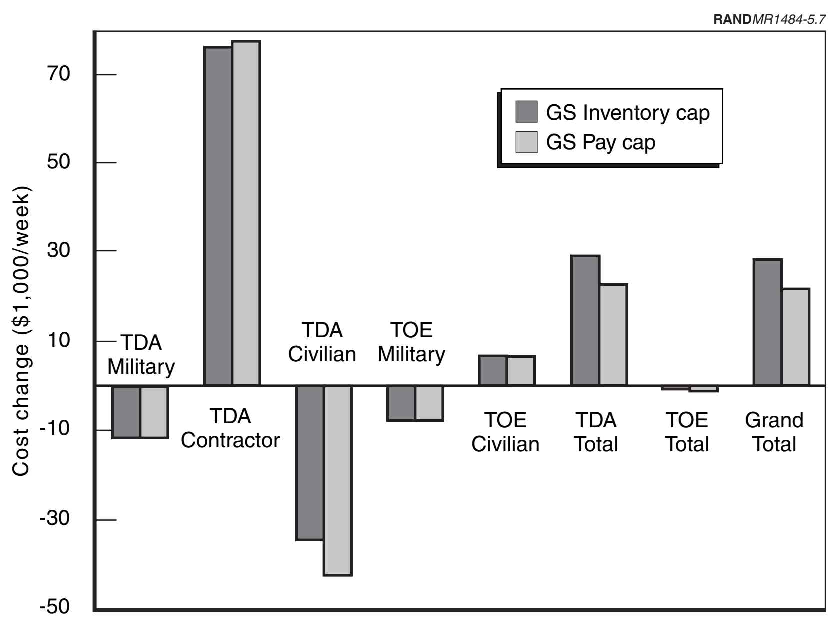

Figure 5.7—Cost Effects of Different Constraints for Increased Workload

hire relatively expensive contractors, for whom there are no salary limits. Before discussing why this is not the case, consider Figure 5.8, which shows that the assignment changes made by the linear programming model are not at all obvious.

Figure 5.8 shows the fairly complicated trades that the linear programming model makes to minimize the costs of doing all of the IT work under the constraints for the first scenario. The bars in this chart show the differences in inventories from the base case. For example, a bar that shows –2 means that two fewer personnel in this

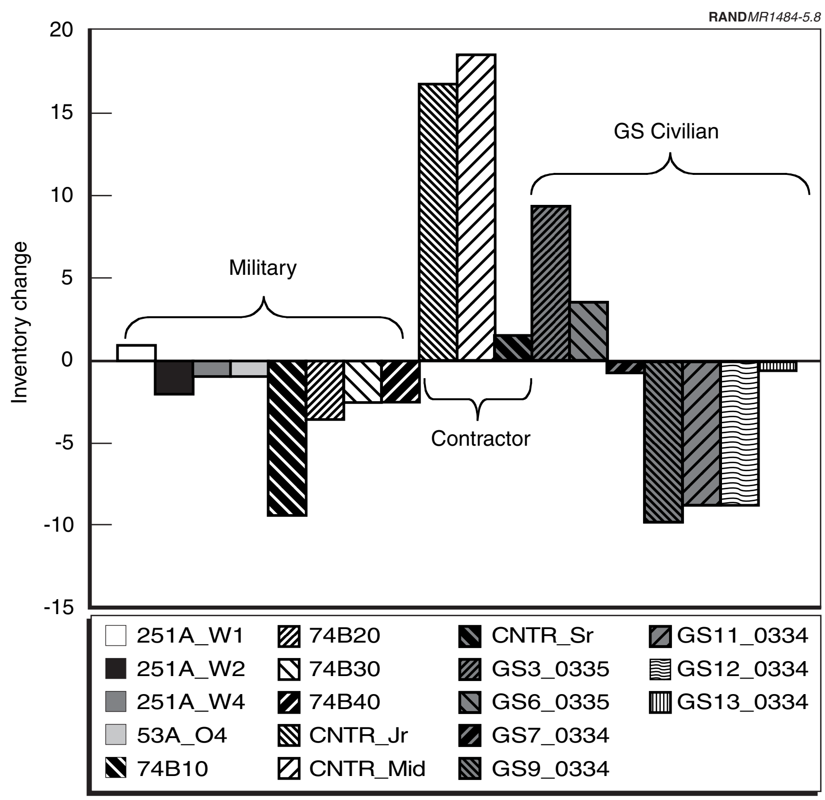

Figure 5.8—Detailed Inventory Changes with Government Civilian Inventory Cap

category were used than in the base case with increased workload. Every category of personnel—officers, warrant officers, enlisted personnel, and government civilians—has been affected. The military decreases reflect replacement of military TDA personnel by civilians or contractors and replacement of some military TOE personnel by government civilians. Increases in GS3 and GS6 personnel are needed to fill some military TOE and TDA slots.[2] New contractor hires are needed to replace more-senior government civilians. The necessary trade-offs to minimize costs shown in this figure would not be easy to determine by hand or with a simple spreadsheet.

Figure 5.9 shows how the solution to minimizing the cost of doing the work changes when the salary cap is imposed. The figure com-

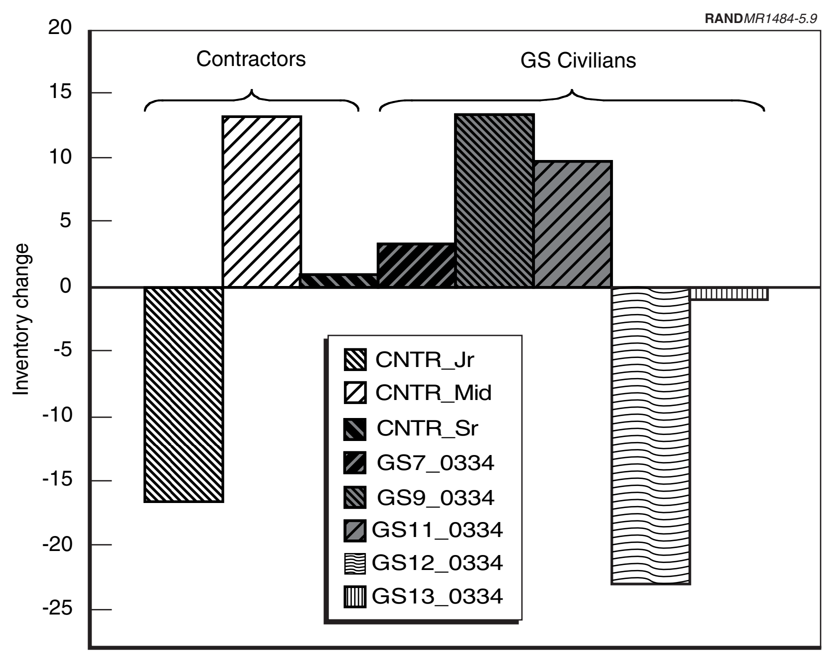

Figure 5.9—Comparison of Pay Cap Scenario to Inventory Cap Scenario

[2]The complete output of the model also shows that personnel in levels GS9, GS12, and GS13 are moved into TOE positions.

pares the personnel used in the salary cap case to those used in the inventory cap case. The most obvious difference is that, with the salary cap, the model "decided" to hire fewer GS12 personnel; instead replacing them with midlevel contractors.[3] In addition, the solution hired 16 fewer "junior" contractors and hired more lower-level government civilians than in the previous case.

This explains why the case with the salary cap is slightly cheaper than the case with the inventory cap: the model has the flexibility to "violate" civilian inventory limits that the inventory case could not. The model may have "wanted" to hire inexpensive government civilians in the first case, but because of inventory limits it could not and was forced to use more-expensive contractors for some positions.

These two scenarios show how the linear programming approach can be used to study the cost of inflexibility—or of inflexibilities of different types. Specifically, in this example, it is worth almost $7,000 per week to have a great deal of flexibility in government civilian hiring, even if it is necessary to live with a salary cap.[4]

GENERAL OBSERVATIONS

Once the general linear program for this analysis has been written, making adjustments for assignment rules, introducing new constraints, and using different objective functions are easy. The examples discussed above show the flexibility of the model and the nature of policy changes that can be addressed. The consequences of these changes can be fairly complicated (as seen in Figure 5.8), even with a very basic construction such as the one we used for Fort Bragg.

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[3]The total number of new midlevel contractors does not match the decrease in GS12 personnel. This is because the model not only hires new midlevel contractors but also moves some who had been in GS11 positions to GS12 positions. The contractors so moved are replaced by newly hired GS11 personnel, hence the increase in GS11s in this scenario.

[4]While this amount may not seem significant, it could pay for about nine personnel at the GS5 level. The point of this exercise is to show the insight possible from experimenting with the model, not to estimate actual costs. Sensitivity analysis with different assumptions about costs and different assumptions about assignment options would be very easy in this framework.

Although outcomes in our examples are not necessarily surprising (limiting the number of government personnel obviously will require the hiring of more contractors, for example), the detailed adjustments needed to minimize costs can lead to more insight into unexpected consequences of assignment or budget decisions.

Chapter Six

CONCLUSIONS AND RECOMMENDATIONS

The scenarios discussed in Chapter Five illustrate the types of policy problems that can be addressed with a simple linear programming model. While these examples are not detailed enough to suggest any specific changes in policy for IT personnel, they do raise several important general points about using the approach to assist decisionmakers.

A SYSTEMATIC DETERMINATION OF WHO CAN DO WHAT IS CRUCIAL

Key to applying this type of model is the determination of the personnel who are allowed to accomplish different jobs. At the most general level, this is related to decisions about which IT jobs are “inherently governmental.” The inventory of functions considered to be commercial activities (not inherently governmental), required under the FAIR Act, is maintained by the Office of the Assistant Secretary of the Army for Manpower and Reserve Affairs (ASA(M&RA)). In modeling the possibility of outsourcing a function, however, the ASA(M&RA) list is only a starting point because it only contains functions or activities that the Army performs to carry out its missions—not individual positions in Army units.

The FAIR inventory is helpful in determining categories of positions that *could* be outsourced to contractors, but, to set up the linear programming model, a correspondence such as that in Table 4.7 must be developed to specify which positions contractor personnel could fill. A similar mapping of other positions is necessary to make clear the substitutions of labor that are allowed for specific positions.

This is not a deep insight, but it is not clear that the Army has made such a determination. It will be difficult to study the consequences of expanding the pool of IT personnel for new Army positions until that determination is made.

CONSEQUENCES OF POLICY CHANGES CAN BE QUANTIFIED

Testing the model with Fort Bragg showed that most of the data required are easy to find or develop. Standard costing data for military and government personnel can be found with the AMCOS model, and potential civilian contracting costs can be estimated using CPS data. Current and projected TOE personnel requirements are also relatively easy to obtain. At the installation level, TDA information is readily available—as it should be because that is where TDA management is accomplished—but, although the POSCO file contains information about military TDA *authorizations*, we could find no centralized source of TDA *inventories* for military or civilian personnel. Obtaining this information at levels above the installation would be the most difficult data-gathering problem associated with expanding the model.

As we have seen in the examples of Chapter Five, the cost and personnel inventory consequences of different assumptions about allowable assignments and different constraints are easily determined and are useful. A policymaker who can argue that more flexibility in hiring government civilians could save an installation $7,000 per week is in a better position to influence change than someone who cannot make a quantitative argument.

POLICY CONSEQUENCES CAN BE BETTER UNDERSTOOD

Policy changes often have unexpected consequences. In the above example of filling the Army's IT needs when an installation receives only 90 percent of its authorizations, we expected (perhaps naively) that a constraint on government personnel costs would lead to a more expensive force than a constraint on government personnel inventories because the budget limitation might force the use of more-expensive contractors for whom there was no budget limit. The lower-cost result with the budget constraint forced us to examine our assumptions and constraints more closely and led to a deeper understanding of the potential hiring incentives introduced by the different constraints. Unexpected model results can lead to model modifications that more closely mirror reality or encourage an analyst to recalibrate his or her expectations. In either case, the model has contributed to understanding and will provide better information for decisionmakers.

A WIDE VARIETY OF CONSEQUENCES CAN BE STUDIED

In this report, we focused on examples that had the objective of minimizing costs of the IT workforce. Other objective functions can be used just as easily. For example, maximizing the number of military personnel in supervisory positions could be an objective. The structure of this type of model is flexible enough to address a wide variety of policy issues and constraints at the same time. Budget constraints, acceptable manning limitations, and different levels of assignment flexibility are easy to incorporate.

RECOMMENDATIONS

There are several ways to address broader Army issues by developing larger versions of the simple model we have described. Earlier, we mentioned four "archetype" Army installations: force projection, training, depot/arsenal, and headquarters. Similar models could be developed for other archetypes, and they could be combined into an Army-wide model of IT requirements. This would be especially useful for studying Army-wide and regional consequences of changes in assignment policies for civil service personnel as well as the effects of regional labor market constraints that could affect outsourcing.

A multiperiod model can also be developed to account for accessions, career development, and attrition over specified planning periods.[1] Finally, the model can be applied to other important occupational specialties besides the IT field.

---

[1]This would be similar to the work done in *An Analysis of Personnel Distribution Options for the Chief of Staff, Army,* but would introduce the complication of non-military labor sources.

Data collection would be time-consuming—especially in the case of Army-wide data for government civilians, but all of these enhancements would help the Army develop a realistic strategic planning framework for the workforce of the future.

Appendix

IMPLEMENTATION OF THE LINEAR PROGRAM MODEL

IMPLEMENTATION AND COMPUTATIONAL EXPERIENCE

Three versions of the model were implemented using the General Algebraic Modeling System (GAMS) for generation and solution (Brooke, Kendrick, and Meeraus 1992). The first version, called the Total Cost Model, used objective function (3.1) and constraints (3.3), (3.4), (3.5), (3.6), and (3.8) of Chapter Three. The Total Cost Model was used in Chapter Five to determine the weekly costs of the authorized workforce and shadow workforce at Fort Bragg. A second version, called the Workforce Constrained Model, was derived from the Total Cost Model by partitioning constraint (3.3)

$$\sum_{j \in J} \sum_{k \in K} \sum_{l \in L} X_{ijkl} \leq INV_i + Z_i,\ i \in I$$

into separate sets of inventory constraints for military (3.3a) and Civil Service (3.3b) personnel.

$$\sum_{j \in J} \sum_{k \in K} \sum_{l \in L} X_{ijkl} = INV_i + Z_i,\ i \in I^A \qquad (3.3a)$$

$$\sum_{j \in J} \sum_{k \in K} \sum_{l \in L} X_{ijkl} \leq INV_i + Z_i,\ i \in I^{CS} \qquad (3.3b)$$

Constraint set (3.3a) requires that all military personnel be assigned jobs. Constraint set (3.3b) is less restrictive, requiring only that the number of civil service personnel of a particular kind assigned to job openings not exceed the available inventory. The penalty costs, P_i paid for each person added to inventory, were made very large to keep variable Z_i at value zero. The third version, the Budget Constrained Model, was created from the Workforce Constrained Model by removing constraint set (3.3b) and adding constraint (3.7) from Chapter Three.

The GAMS implementation code shown below conforms to the algebraic formulation for the Total Cost Model with one exception. For convenience, an indicator parameter, ALLOWED(i,j,k,l), was introduced to easily institute policies regarding the assignment of types of personnel/skill combinations to types of jobs. ALLOWED(i,j,k,l) has the value "1" if person *i* is authorized to perform job *j* in organization *k* by document *l* and value "0" otherwise. This parameter appears in constraint definitions in the form "X(i,j,k,l)$(ALLOWED(i,j,k,l) EQ 1)" and is interpreted as "include X(i,j,k,l) in the sum if ALLOWED(i,j,k,l) equals 1."

The largest problem solved in this research contained 90 decision variables and 74 constraints. Using the BDM linear programming algorithm, a solution was obtained in 0.06 seconds of central processing unit time on a Dell Optiplex GX-110 computer with a Pentium PIII/733 microprocessor operating under the Microsoft Windows 98 operating system.

Table A.1

GAMS Computer Program

```
GAMS Rev 120  Windows NT/95/98          11/15/01 12:35:32           PAGE          1
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n

*RAND Project AR038 941T
*June 27, 2001  - Base Case
*
*14 Nov   -   Military Costs revised to AMCOS Lifecycle Composite Rates
*              GS Costs revised to AMCOS Lifecycle Default Rates
*              Revised Penalties to equal AMCOS Rates
*
*
GAMS Rev 120      Windows NT/95/98               11/15/01 12:35:32      PAGE        2
INFORMATION TECHNOLOGY STRATEGIC PLANNING PROBLEM
*    This Model is used to assign officer, warrant, enlisted, DA civilians
*    and civilian contractors to Army organizations to meet
*    Requirements at an installation
*
SETS
   I      personnel type
          ACTIVE(I)          active duty military
          OFFICER(I)         officer personnel
          MILITARY(I)        mlitary personnel
          DACIV(I)           Army civil service personnel
   J                         job type
   K                         organization type
   L                         authorization document type (MTOE or TDA);
*
PARAMETERS
   INVENTORY(i)              number of worker I available
   PERS_COST(i)              cost of worker I
   PERS_REQ(j,k,l)           number of jobs J authorized in org'n K by auth L
   PERS_ADD(j,k,l)           number of jobs J performed but not authorized in
                                                                    org'n K by
*                                         auth L
   ALLOWED(i,j,k,l)          binary matrix used to control permissible assignments
*                                        of worker I to job J in org'n K in auth L

MIL_RQ(j,k,l)                minimum % of mil personnel doing job J in org'n K in
                                                                        auth L
DA_CIV_RQ(j,k,l)             minimum % of DA civilians doing job J in org'n K in
                                                                        auth L
E_Penalty(i)
;
```

Table A.1—continued

```
*
VARIABLES
   TOTALCOST      total cost of assigning workers to jobs
   X(i,j,k,l)     number of workers I doing job J in org'n K in category L
   E_Inv(i)       elasticc ariable on inventory constraint
;
POSITIVE VARIABLES X, E_Inv;
*
EQUATIONS
   OBJ_FCN
   PERS_LIMIT(i)        do not exceed INVENTORY(I)
   STAFFING(j,k,l)      meet PERS_REQ
*
   OFF_RATIO(j,k,l)     meet or exceed ratio of officers to workers in
                                                                  workforce
   DAC_RATIO(j,k,l)     meet or exceed ratio of DA civ to workers J in
                                                                  workforce
   MIL_RATIO(j,k,l)     meet or exceed ratio of milper to workers J in
                                                                 workforce;
*
************************EQUATION DEFINITIONS*********************
                                                                 **********
PERS_LIMIT(i)                    SUM((j,k,l), X(i,j,k,l)$(ALLOWED(i,j,k,l) EQ
                                                                        1))
                                     =L=INVENTORY(i)+E_Inv(i);
*
STAFFING(j,k,l)$PERS_REQ(j,k,l).. SUM(I, X(i,j,k,l)$(ALLOWED(i,j,k,l) EQ
                                                                        1))
                                  =G=PERS_REQ(j,k,l)+PERS_ADD(j,k,l);
*
OFF_RATIO(j,k,l)$OFFICER_RQ(j,k,l).. SUM(I $ OFFICER(i), X(i,j,k,l)
                                                  $(ALLOWED(i,j,k,l) EQ 1))
             =G=(OFFICER_RQ(j,k,l)/100)*SUM(I, X(i,j,k,l)$(ALLOWED(i,j,k,
                                                                l) EQ 1));
*
DAC_RATIO(j,k,l)$DA_CIV_RQ(j,k,l).. SUM(I $ DACIV(i),X(i,j,k,l)
                                                  $(ALLOWED(i,j,k,l) EQ 1))
              =G=(DA_CIV_RQ(j,k,l)/100)*SUM(I, X(i,j,k,l)$(ALLOWED(i,j,k,
                                                                1) EQ 1));
*
MIL_RATIO(j,k,l)$MIL_RQ(j,k,l).. SUM(I $ MILITARY(i),X(i,j,k,l)
                                                  $(ALLOWED(i,j,k,l) EQ 1))
                 =G=(MIL_RQ(j,k,l)/100)*SUM(I, X(i,j,k,l)$(ALLOWED(i,j,k,
                                                                1) EQ 1));
*
```

Table A.1—continued

```
OBJ_FCN..          TOTALCOST=E=SUM((i,j,k,l), PERS_COST(i)*X(i,j,k,l)$
                              (ALLOWED(i,j,k,l) EQ 1))+SUM(i, E_Inv(i)
                                                          *E_Penalty(i));
MODEL IT_IM /ALL/;
******************************DATA DEFINITIONS********************************
                                                                      ******
SETS
   I        personnel type
            /74B40,74B30,74B20,74B10,
             53A_O5,53A_O4,53A_O3,
             251A_W4,251A_W3,251A_W2,251A_W1,
             GS13_0334,
             GS12_0334,
             GS11_0334,
             GS09_0334,
             GS07_0334/
*            CNTR_Sr,CNTR_Mid,CNTR_Jr
        OFFICER(I)     officer personnel
         /53A_O5,53A_O4,53A_O3,251A_W4,251A_W3,251A_W2,251A_W1/
        MILITARY(I)    military personnel
         /74B40,74B30,74B20,74B10,53A_O5,53A_O4,53A_O3,251A_W4,
                       251A_W3,251A_W2,251A_W1/
        DACIV(I)       Army civil service personnel
                       /GS13_0334,
                        GS12_0334,
                        GS11_0334,
                        GS09_0334,
                        GS07_0334/
   J           job type
                       /SwAnal_Spv,InfoSys_Spv,GCCSAnal,
                        Anal_TmCf,InfoSys_TmCf,
                        InfoSys_SrOp,SwAnal_Sr,LANMgr_Sr,
                        InfoSys_Op,SwAnal,
                        AutoMgmtOff_Sr
                        AutoMgmtOff,
                        InfoMgmtOff,
                        DPTech_Sr,
                        DPTech,
*
*       *               CS334_13,
                        CS334_12,
                        CS334_11,
                        CS334_09,
```

Table A.1—continued

```
                         CS334_07/
*
  K          organization type
                         /XVIIICorps,82ndABNDiv,
                         WomackAMC,Garrison/
  L          authorization type
                /TOE,TDA/;
*
PARAMETERS
  INVENTORY(i)       number of worker I available
*                    Enlisted fill data as of Mar 01
                     /74B40              10
                      74B30              14
                      74B20              25
                      74B10              81
*                    Officer fill data as of Mar 00 modified
                      53A_O5              4
                      53A_O4              7
                      53A_O3              1
*                    Warrant Officer fill data as of Mar 01 modified
                      251A_W4             5
                      251A_W3             1
                      251A_W2             2
                      251A_W1             0
*                    Civilian fill data distributed by DA average
*
                      GS13_0334           2
                      GS12_0334          33
                      GS11_0334          33
                      GS09_0334          37
                      GS07_0334          3/
*
  E_Penalty(i)       penalty for exceeding INVENTORY limits
                     /74B40              20000
                      74B30              20000
                      74B20              20000
                      74B10              20000
                      53A_O5             20000
                      53A_O4             20000
                      53A_O3             20000
                      251A_W4            20000
                      251A_W3            20000
                      251A_W2            20000
                      251A_W1            20000
                      GS13_0334          20000
```

Table A.1—continued

```
                        GS12_0334              20000
                        GS11_0334              20000
                        GS09_0334              20000
                        GS07_0334              20000/
*                       CNTR_Sr                20000
*                       CNTR_Mid               20000
*                       CNTR_Jr                20000/
*
   PARAMETER PERS_COST(i)  cost of worker I for one week
*                       Mil Pers Cost is the AMCOS lifecycle composite weekly
                                                                          rate
                       /74B40                   1148
                        74B30                    969
                        74B20                    825
                        74B10                    704
                        53A_O5                  2187
                        53A_O4                  1844
                        53A_O3                  1525
                        251A_W4                 1777
                        251A_W3                 1456
                        251A_W2                 1232
                        251A_W1                 1075
*                       GS costs include salary, benefits and retirement per
                                                                         AMCOS
*
                        GS13_0334               1831
                        GS12_0334               1528
                        GS11_0334               1247
                        GS09_0334               1032
                        GS07_0334                846/
*
*                       CNTR_Sr                 2318
*                       CNTR_Mid                2254
*                       CNTR_Jr                 1834/
                          ;
   TABLE PERS_REQ(j,k,l) number of job J authorized in org'n K by auth L
*               Authorizations based on Mar 01 POSCO
                         XVIIICorps.    82ndABNDiv.   Womack
                         TOE            TOE           AMC.TDA
                                                                Garrison.TDA
   SwAnal_Spv            3              1
   InfoSys_Spv           2              2
   GCCSAnal                                                         2
   Anal_TmCf             6              2
   InfoSys_TmCf          4                            1             1
```

Table A.1—continued

```
     InfoSys_SrOp        10                                      2
     SwAnal_Sr           7            2
     LANMgr_Sr           4
     InfoSys_Op          27                         2            3
     SwAnal              37           12
     AutoMgmtOff_Sr      4
     AutoMgmtOff         5            2
     InfoMgmtOff         1
     DPTech_Sr           4            2
     DPTech              2
   *
     CS334_13            0            0             1            1
     CS334_12            0            0             2            31
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INFORMATION TECHNOLOGY STRATEGIC PLANNING PROBLEM


     CS334_11            0            0             3            30
     CS334_09            0            0             3            34
     CS334_07            0            0             0            3
       ;
   TABLE PERS_ADD(j,k,l) number of jobs J performed but not authorized in
                                                                  org'n K
   *           These shadow postions have not been determined.
                         XVIIICorps.  82ndABNDiv.   Womack
                         TOE          TOE           AMC.TDA
                                                          Garrison.TDA
     SwAnal_Spv          0            0             0            0
     InfoSys_Spv         0            0             0            0
     GCCSAnal            0            0             0            0
     Anal_TmCf           0            0             0            0
     InfoSys_TmCf        0            0             0            0
     InfoSys_SrOp        0            0             0            0
     SwAnal_Sr           0            0             0            0
     LANMgr_Sr           0            0             0            0
     InfoSys_Op          0            0             0            0
     SwAnal    0         0            0             0            0
     AutoMgmtOff_Sr      0            0             0            0
     AutoMgmtOff         0            0             0            0
     InfoMgmtOff         0            0             0            0
     DPTech_Sr           0            0             0            0
     DPTech
   *
     CS334_13            0            0             0            0
     CS334_12            0            0             0            0
```

Table A.1—continued

```
     CS334_11              0              0              0              0
     CS334_09              0              0              0              0
     CS334_07              0              0              0              0
       ;
TABLE OFFICER_RQ(j,k,l) min % of officers doing job J in org'n K in auth L
*              Enter a number greater than 0.0 if the job requires an officer minimum
                           XVIIICorps.    82ndABNDiv.    Womack
                           TOE            TOE            AMC.TDA
                                                               Garrison.TDA
     AutoMgmtOff_Sr         100.0          100.0           0.0         0.0
     AutoMgmtOff            100.0          100.0           0.0         0.0
     InfoMgmtOff            100.0            0.0           0.0         0.0
     DPTech_Sr              100.0          100.0           0.0         0.0
     DPTech                 100.0            0.0           0.0         0.0
          ;
     TABLE MIL_RQ(j,k,l) min % of mil personnel doing job J in org'n K in auth L
*              Enter a number greater than 0.0 if the job requires a military minimum
                           XVIIICorps.    82ndABNDiv.    Womack
                           TOE            TOE            AMC.TDA
                                                               Garrison.TDA
     SwAnal_Spv             100.0          100.0           0.0         0.0
     InfoSys_Spv            100.0          100.0           0.0         0.0
     GCCSAnal                 0.0            0.0           0.0         0.0
     Anal_TmCf              100.0          100.0           0.0         0.0
     nfoSys_TmCf            100.0            0.0           0.0         0.0
     InfoSys_SrOp           100.0            0.0           0.0         0.0
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INFORMATION TECHNOLOGY STRATEGIC PLANNING PROBLEM
     SwAnal_Sr              100.0          100.0           0.0         0.0
     LANMgr_Sr              100.0            0.0           0.0         0.0
     InfoSys_Op             100.0            0.0           0.0         0.0
     SwAnal                 100.0          100.0           0.0         0.0
     AutoMgmtOff_Sr         100.0            0.0           0.0         0.0
     AutoMgmtOff            100.0          100.0           0.0         0.0
     InfoMgmtOff            100.0            0.0           0.0         0.0
     DPTech_Sr              100.0          100.0           0.0         0.0
     DPTech                 100.0            0.0           0.0         0.0
          ;
     TABLE DA_CIV_RQ(j,k,l)  min % of DA civilians doing job J in org'n K in auth L
```

Table A.1—continued

```
                           XVIIICorps.   82ndABNDiv.   Womack
                           TOE           TOE           AMC.TDA
                                                                 Garrison.TDA
     SwAnal_Spv              0.0           0.0           0.0         0.0
     InfoSys_Spv             0.0           0.0           0.0         0.0
     GCCSAnal                0.0           0.0           0.0         0.0
     Anal_TmCf               0.0           0.0           0.0         0.0
     InfoSys_TmCf            0.0           0.0           0.0         0.0
     InfoSys_SrOp            0.0           0.0           0.0         0.0
     SwAnal_Sr               0.0           0.0           0.0         0.0
     LANMgr_Sr               0.0           0.0           0.0         0.0
     InfoSys_Op              0.0           0.0           0.0         0.0
     SwAnal                  0.0           0.0           0.0         0.0
     AutoMgmtOff_Sr          0.0           0.0           0.0         0.0
     AutoMgmtOff             0.0           0.0           0.0         0.0
     InfoMgmtOff             0.0           0.0           0.0         0.0
     DPTech_Sr               0.0           0.0           0.0         0.0
     DPTech                  0.0           0.0           0.0         0.0
     CS334_13                0.0           0.0           0.0         0.0
     CS334_12                0.0           0.0           0.0         0.0
     CS334_11                0.0           0.0           0.0         0.0
     CS334_09                0.0           0.0           0.0         0.0
     CS334_07                0.0           0.0           0.0         0.0
        ;
     TABLE ALLOWED(i,j,k,l)   binary matrix of establish permissible
                                                             assignments
*      A 1 (0) indicates that this person.job combination may be used
*          to satisfy a job requirement in this organization.document type.
                                       XVIIICorps.TOE   82ndABNDiv.TOE
     74B40.(SwAnal_Spv,InfoSys_Spv)      1                1
     74B30.Anal_TmCf                     1                1
     74B30.InfoSys_TmCf                  1                0
     74B20.InfoSys_SrOp                  1                0
     74B20.SwAnal_Sr                     1                1
     74B20.LANMgr_Sr                     1                0
     74B10.InfoSys_Op                    1                0
     74B10.SwAnal                        1                1
     53A_O5.AutoMgmtOff_Sr               1                0
     53A_O4.AutoMgmtOff                  1                1
     53A_O3.InfoMgmtOff                  1                0
*
*                Optional to allow assignments to jobs usually held by
                 someone one grade senior?
*                Example: Captains can fill Majors jobs
*    53A_O3.(InfoMgmtOff,AutoMgmtOff)    1                1
```

Table A.1—continued

```
*              Example: Allowable to assign W4s to 53A Captains jobs
*  251A_W4.InfoMgmtOff          1             1
   251A_W4.DPTech_Sr            1             1
   251A_W3.DPTech_Sr            1             1
   251A_W2.DPTech               1             0
   251A_W1.DPTech               1             0
      +                         WomackAMC.TDA Garrison.TDA
   74B40.GCCSAnal               0             1
   74B30.InfoSys_TmCf           1             1
   74B20.InfoSys_SrOp           0             1
   74B10.InfoSys_Op             1             1
*
*              Possibly allow GS assignment to Military jobs
*              Example: Allow GS_15 in 334 Field to replace LTC in 53A in TDAs
*
   GS13_0334.CS334_13           1             1
   GS12_0334.CS334_12           1             1
   GS11_0334.CS334_11           1             1
   GS09_0334.CS334_09           1             1
   GS07_0334.CS334_07           0             1
*
*              Allowable Contractor to GS Career Field Substitutions
*
*  CNTR_Sr.CS334_13             1             1
*  CNTR_Mid.CS334_12            1             1
*  CNTR_Mid.CS334_11            1             1
*  CNTR_Jr.CS334_09             1             1
       ;
************************SOLVE AND OUTPUT STATEMENTS**************************
SOLVE IT_IM USING LP MINIMIZING TOTALCOST
PARAMETER TRUE_COST  Value of TOTALCOST less Penalties For Exceeding Inventory;
   TRUE_COST=TOTALCOST.L-SUM(i,E_Inv.L(i)* E_Penalty(i));
DISPLAY TRUE_COST
```

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