Workforce Transition Model for DOE-AL Non-Nuclear Reconfiguration

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Summary

The Pacific Northwest Laboratory (PNL) was tasked by the U.S. Department of Energy Albuquerque Field Office (DOE-AL) to develop a workforce assessment and transition planning tool to support integrated decision making at a single DOE installation. The planning tool permits coordinated, integrated workforce planning to manage growth, decline, or transition within a DOE installation. The tool enhances the links and provides commonality between strategic, programmatic, and operations planners and human resources. Successful development and subsequent complex-wide implementation of the model will also facilitate planning at the national level by enforcing a consistent format on data that are now collected by installations in corporate-specific formats that are not amenable to national-level analyses.

The workforce assessment and transition planning tool consists of two components: the Workforce Transition Model and the Workforce Budget Constraint Model. The Workforce Transition Model, the preponderant of the two, assists decision makers to identify and evaluates alternatives for transitioning the current workforce to meet the skills required to support projected workforce requirements. The Workforce Budget Constraint Model helps estimate the number of personnel that will be affected given a workforce budget increase or decrease and assists in identifying how the corresponding hirings or layoffs should be distributed across the common occupational classification system (COCS) occupations. The conceptual models and the computer implementation are described.

Contents

Summary	iii
1.0 Introduction	1.1
1.1 Background	1.2
1.2 Scope	1.2
1.3 Solution	1.2
2.0 Workforce Management Paradigm	2.1
3.0 Workforce Transition Model	3.1
3.1 Assumptions	3.1
3.2 Model Inputs	3.2
3.2.1 Hiring Costs	3.2
3.2.2 Layoff Costs	3.3
3.2.3 Training Costs	3.3
Prohibited Transitions	3.4
Transitions with Training Costs	3.7
No-Cost Transitions	3.7
3.2.4 Calculation of Training Costs	3.7
3.2.5 Current Workforce Characterization	3.8
3.2.6 Projected Workforce Requirements	3.8
3.3 The Model	3.13
3.3.1 The Linear Program	3.13
The Objective Function	3.13
Constraints	3.14
Additional Constraints	3.15
The Complete Model	3.16
3.3.2 Example Model	3.16
4.0 Workforce Budget Constraint Model	4.1
4.1 The Objective Function	4.1
4.2 Constraints	4.2
4.3 The Complete Model	4.2
5.0 Computer Implementation	5.1
6.0 Conclusions	6.1
7.0 References	7.1
Appendix A - Common Occupation Classification System (COCS)	A.1
Appendix B - Linear Programming Primer	B.1

Figures

2.1 Workforce Management Paradigm	2.2
2.2 EM Workforce Transition Model	2.3

Tables

3.1 Waste Remediation FTE Requirements Used in Workforce Transition Model	3.9
3.2 EM Occupational Distribution	3.11
3.3 Workforce Example Levels	3.17
3.4 Workforce Example Training Costs	3.17

1.0 Introduction

The Pacific Northwest Laboratory (PNL) was tasked by the U.S. Department of Energy Albuquerque Field Office (DOE-AL) to develop a workforce assessment and transition planning tool to support integrated decision making at a single DOE installation. The Workforce Transition Model permits coordinated, integrated workforce planning to manage growth, decline, or transition within a DOE installation. The model enhances the links and provides commonality between strategic, programmatic, and operations planners and human resources. Successful development and subsequent complex-wide implementation of the model also will facilitate planning at the national level by enforcing a consistent format on data that are now collected by installations in corporate-specific formats that are not amenable to national-level analyses.

Workforce planning activities at DOE installations are complicated by the need to cut costs as well as the non-nuclear reconfiguration effort. The result is that installations are being asked to balance constant or increasing workloads with decreasing resources. Efforts are further complicated by work specifications and schedules that are ambiguous and constantly changing. To simplify workforce planning activities and make them more productive, it is necessary for DOE to clearly specify contractor requirements and for contractors to respond quickly and consistently to these requirements with workforce and budget projections. These changes will allow workforce planning to be driven by requirements instead of budgets.

Production and transition requirements, workforce planning, and the workforce budget are directly related. In the past, the composition of the workforce was driven by budget figures. The Workforce Transition Model was developed under the premise that the desired approach is to estimate workforce requirements based on production and transition requirements. The appropriate budget then follows directly from the workforce requirements. This approach ensures that production and transition requirements, the workforce composition, and the workforce budget are in alignment.

The Workforce Transition Model implements the desired approach by providing a mechanism for installations to evaluate production and transition requirements. Evaluations may take several forms. First, if DOE specifies transition requirements, installations will be able to estimate workforce transition requirements and corresponding costs. Second, if DOE specifies production requirements, installations will be able to estimate workforce requirements and characterization. Third, if DOE specifies budget restrictions, installations will be able to determine the corresponding level of work that can be accomplished.

The methodology is based on DOE specifications that include production and transition schedules to estimate workforce requirements, what cost elements are allowed, what cost elements are not allowed, and how costs are calculated. The methodology encompasses assumptions and guidelines applied consistently across all installations. Assumptions address critical skills, training, reduction-in-force (RIF) packages, projected skills required to support future work, retention packages, and other related elements that affect the workforce transition. Defining DOE specifications and the underlying assumptions are key to the development of this methodology. This enhances the validity of the results and facilitates reporting of consistent data among installations.

1.1 Background

As part of the effort to reduce costs, DOE is consolidating its non-nuclear production facilities. Specifically, the Mound and Pinellas Plants defense program (DP) missions are targeted for shutdown by 1996 with workloads being transferred to Los Alamos National Laboratory (LANL), Savannah River Site (SRS), Kansas City Plant (KCP), and Sandia National Laboratories (SNL). Following termination of the DP missions, environmental restoration and waste management (EM) will begin at both Mound and Pinellas. These missions are expected to last approximately 30 years at Mound and 3 years at Pinellas. Concurrently, DOE is implementing budget cuts across DP that further complicate transition planning.

Further restructuring of the DOE workforce is also expected over the next several years as DOE realigns its mission. Thus, all installations will experience significant workforce restructuring. Also, as EM progresses at each installation, workforce planning must be conducted to accommodate the different workforce requirements of each clean-up stage. Although this project targets the DP to EM transition at Mound and Pinellas, the approach and methods are generic so as to be applicable to all installations within the DOE complex.

1.2 Scope

Few tools exist to assist decision makers implement a smooth transition that minimizes transition costs, minimizes the negative effect on the workforce, and results in the most efficient workforce configuration. Without such tools, decision makers have limited planning capability and tend to revert to a strategy that reduces budgets across all programs, by an equal amount, irrespective of the importance of each program. This approach, albeit simple, will result in an inefficient configuration that will require additional funding to rectify because critical personnel will be cut along with less critical personnel. This approach also may result in prolonged inefficiencies already present in the workforce planning process. The critical personnel, or their equivalent, will have to be rehired, often at a higher salary, and less critical personnel, who could have been released, are still part of the organization.

The lack of planning tools and integration between the installations and the Field Office also fosters a budget-driven workforce plan that bypasses the installations' input. Planning models installed at the installation level provide installations the ability to quickly and reliably respond to DOE data requests. This allows the installations to be more proactive and produce requirements-driven workforce plans.

1.3 Solution

In response to these needs, DOE-AL is developing methods to facilitate the transition. These include standardizing data-reporting formats between DOE-AL and its assigned management and operations contractors, and workforce transition models to identify the optimal transition strategy. The Common Occupational Classification System (COCS) (Holmes et al. 1992) is chosen as the standard occupational reporting format (see Appendix A for a short description of the COCS). This is to ensure all installations report in a common format, allowing DOE-AL to aggregate data for complex-level planning. The models include a Workforce Transition Model to help plan medium-term workforce reconfiguration at an installation and a Workforce Budget Constraint

Model to quantify the workforce impact of a budget cut. The components are described in the chapters that follow.

2.0 Workforce Management Paradigm

The Workforce Transition Model addresses the specific task of determining how best to transition the current workforce to a projected workforce configuration given the current workforce characterization, the projected workforce characterization, and related transition costs. Surrounding this task are other related tasks that are either performed in parallel or provide input to the Workforce Transition Model. This section describes the role of the workforce management process in general and illustrates the role of the Workforce Transition Model in this process.

The question facing workforce planners is how best to transition the workforce from its current state to a state supporting the future mission of the installation. This is the Workforce Transition Strategy. The choice of strategy is dependent on transition costs, the environmental status of the installation, and DOE's remediation plans for the installation. The process of developing the Workforce Transition Strategy is given in Figure 2.1. The output of the process, the Workforce Transition Strategy, is shown on the right-hand side of the diagram; the processes involved in developing the strategy are given in the middle of the diagram; and the system parameters governing the transition process are given as inputs on the left-hand side of the diagram.

The dashed box around the Workforce Transition Model module delineates the scope of this project. The inputs to this module are the current workforce characterization, the projected workforce characterization, and the transition costs. The remaining activities specify the functions necessary to obtain the inputs for the Workforce Transition Model. Figure 2.2 isolates the Workforce Transition Model and displays it within the scope of this project. In this figure, the current workforce, projected workforce requirements, and transition costs are given as inputs to the model.

The paradigm illustrated in Figure 2.1 encompasses both DP and EM missions. The two missions are explicitly delineated because the inputs and processes used in the Workforce Transition Model differ based on the future mission type. As DOE prepares to transition active DP installations to EM missions, two workforce transitions are necessary. The first is to prepare the workforce to handle the temporary increase in production levels resulting from the pre-build schedule. When each donor installation terminates production, there will be a short period of zero production levels as the production capabilities are moved to the receiver installations. To avoid product shortages during this period, donor installations are required to produce sufficient excess inventory before they terminate production. This period of increased production is referred to as the pre-build period. Increased staff may, or may not, be required to meet these temporary increases in production.

Input for modeling the DP production transition includes production data such as process flow data, production levels, production schedules, and full-time equivalents (FTEs) per product; the current workforce characterization; and the pre-build schedule. The mechanism for estimating workforce requirements will be based on forecasting tools or Markov chains, typical workforce planning tools. This problem is not currently within the scope of this project and is not addressed further.

The EM Workforce Transition Model, the target of this project, is more complicated than the DP model. The traditional tools for workforce planning are not applicable because historical data are not available. Where DP workforce requirements can be predicted based on past performance,

Workforce Management Paradigm

Figure 2.1. Workforce Management Paradigm

Figure 2.2. EM Workforce Transition Model

EM requirements cannot be based on past performance because little or no EM work has been completed. This requires a different method for estimating EM workforce requirements.

The first two inputs required to estimate EM workforce requirements include installation characterization data and environmental remediation data. Site characterization data describe the environmental properties of the installation and types, dispersion, and concentrations of contaminants resulting from operation of the facility. Environmental remediation data describe the available technologies, their application, staffing requirements, costs, and risks. These data are not yet well developed and require significant expertise. The ReOp (White and Bryant 1993) and PRISM^(a) projects being conducted by DOE as part of the Programmatic Environmental Impact Statement (PEIS) project are attempting to address these problems by analyzing site characterization data and developing automated tools to identify the appropriate class of remediation technologies. Once complete, PRISM will be able to identify the appropriate class of technology, total FTEs to perform the remediation, and costs of applying the method. PRISM will not, however, be able to provide workforce requirements at the COCS level.

The third input required to estimate EM workforce requirements is the EM schedule and DOE's plans for the installation. Depending on DOE's decision to contain and control (C/C), remove and treat (R/T), or some combination of the two, different skills and quantities of skills are necessary. Furthermore, the cost of developing the appropriate workforce mix is an input into

(b) Shay, M. R. October 1993. ARAM/PRISM Environmental Remediation Model, Programmatic Environmental Impact Statement Task, Pacific Northwest Laboratory, Richland, Washington.

DOE's decision on what level of remediation is required for each installation. This feedback is shown in the figure. This demonstrates how the model can be used to help determine the best clean-up strategy for an installation as well as the best strategy for staffing the clean-up mission.

Although the activities necessary to obtain the input data for the Workforce Transition Model are not within the scope of this project, guidelines are provided to assist in estimating these values. This is necessary to facilitate the data collection process and to ensure all installations are using the same procedures. This will enhance consistency among installations.

3.0 Workforce Transition Model

The Workforce Transition Model assists decision makers to identify and evaluate alternatives for transitioning the current workforce to meet the skills required to support projected workforce requirements. This chapter describes the Workforce Transition Model, underlying assumptions, and model inputs.

3.1 Assumptions

Individual- and task-specific data are aggregated by COCS occupation title to address the level of abstraction of the Workforce Transition Model. Although the aggregation does allow superfluous data and minute details to be ignored, it does require valid assumptions specifying what and how the data are aggregated. This section annotates the underlying assumptions of the Workforce Transition Model and assumptions related to the model's input.

- The only model parameters are occupation category; number of employees in each occupation category (current and projected); and hire, layoff, and training costs per occupation category. Within these parameters, all personnel are considered equal. Individual characteristics, such as performance and education differences among workers in the same occupation, are not included because they are tenuous and over-complicate the model. Furthermore, the model is aimed at medium-term planning and individual characteristics are not applicable in that time frame.
- All relationships are linear. There are many aspects related to this model that are obviously non-linear. There is an inverse relationship, however, between the accuracy of the model and the availability of data to instantiate the model. Linear models typically only require average values of performance measures to reflect system performance. Higher-order models require different and more precise data than linear models that are typically not available in most organizations. Thus, either the model must be simplified using linearity assumptions, or assumptions must be made about the data to estimate the unknown parameters of a higher-order model. A simple, linear model was chosen for the following reasons: 1) many workforce models found in the literature are linear; 2) data collection efforts have shown that few organizations possess the data necessary to represent a non-linear model; and 3) developing a higher-order model not only requires assumptions about data values, but also requires additional assumptions about the system's non-linearity because the system is not fully understood.

Linearity is accomplished through the method of the data aggregation and problem formulation. Training costs could be non-linear in that the more employees participating in a particular training program could reduce the cost of the program through economies of scale. Training costs, however, are estimates in the first place, and introducing a sliding scale based on the number of participants would require additional, less reliable, assumptions. Hire and layoff costs could be modeled in non-linear fashions as well, but organizations typically only maintain average hire and layoff costs. Finally, the transitions equations are mass balance equations that must be linear to maintain conservation of mass.

- The only occupation transitions allowed are hire, layoff, or train to new occupation. Furthermore, the only transitions of these types that are allowed are those that contribute to meeting

the projected workforce requirements. Traditional turnover and firings are not included because of the recent RIFs Mound and Pinellas have experienced.

- The time required to train to a new occupation must be sufficiently short to be accomplished within the time frame being analyzed. Furthermore, only single steps in an occupation career progression are allowed. This will prevent unrealistic transitions, under the time frames being analyzed, such as a Laundry Worker becoming a Chemical Engineer. This is not to say a Laundry Worker cannot become a Chemical Engineer; it merely states that this transition cannot occur within the limited time frame under consideration.

3.2 Model Inputs

The Workforce Transition Model uses aggregate workforce salary and characterization data based on the COCS. Specifically, the model uses:

- average hiring costs for each COCS occupation title
- average layoff costs for each COCS occupation title
- average training costs from each COCS occupation title to every other COCS occupation title
- current number of people in each COCS occupation title
- projected number of people in each COCS occupation title given a specific scenario.

The model is installation independent. The input values, however, vary from installation to installation depending on local demographics. Because there are approximately 6,730 parameters (for example, hire costs, layoff costs, training costs), initial values are provided where possible. Each installation, however, needs to ensure the accuracy of the input data.

To simplify the estimation of parameter values, similar costs are estimated as a group. For example, hiring and layoff costs need not be estimated for each COCS occupation title directly. Instead, hire and layoff costs may be estimated for exempt, non-exempt, and hourly categories because installations typically estimate costs for these categories. Each COCS occupation title is designated exempt, non-exempt, or hourly, and the appropriate hire and layoff costs are assigned.

The projected number of people in each category is perhaps the most critical input because it has the greatest impact on the results and is the most difficult to estimate. This entails identifying the future mission of the installation (3 to 7 years) and estimating the workforce requirements to support that mission. Expert opinion and a comprehensive installation characterization are necessary for accurate estimates. Various scenarios may be evaluated by estimating the workforce requirements for different missions such as waste C/C or waste R/T. This flexibility allows installations to evaluate potential alternatives and provide recommendations to DOE in a proactive manner.

3.2.1 Hiring Costs

Hiring costs are generally calculated for two categories: exempt and non-exempt/hourly. The primary difference between the two categories is that exempt hiring costs have a relocation component. Typical hiring costs include:

- human resources (HR) expenses
- interviewers' time - this is the time required by non-HR personnel to interview candidates
- candidate background check - this includes checking references and running a preliminary security check.
- candidate transportation and per diem (exempt)
- relocation costs (exempt) - these include moving expenses and temporary housing
- new employee training - this includes initial orientation and typical on-the-job training required of all new employees.

Other costs may include:

- security clearance
- DOE unallowable expenses covered by the contractor.

Typical hiring costs are:

- without relocation - \$7,800
- with relocation - \$20,400.

These costs are provided as a reference for establishing hiring costs for individual installations. Each installation will have different hiring costs because of the unique local demographics and corporate policies.

3.2.2 Layoff Costs

Calculations of certain layoff costs are specified in each installation's contract with DOE. This includes severance costs that are typically calculated for three categories: exempt, non-exempt, and hourly.

3.2.3 Training Costs

The Workforce Transition Model is a high-level model using the broad occupation-classification levels of the COCS. As such, this model is not designed to be comprehensive or to include unique situations. It is designed to address general occupational mobility for medium-term planning and is based on average or typical behavior. For example, training from a crafts occupation to an engineer in a 1- to 7-year time span does not generally occur and thus is prohibited in the model for simplicity. It is possible, however, that an employee with an engineering degree may be working as a craftsperson. In this situation, it may be wiser to elevate the craftsperson rather than hire a new engineer. Situations such as this are individual specific and, in turn, rare. To include all possible unique situations would over-complicate the model by requiring an extensive catalog of individual skills and a plethora of infrequently occurring transitions.

Training costs are divided into two categories: occupational training costs and skills-based training costs. Employees participate in skills-based training to maintain or enhance skills related

to the employee's current occupation. These are individual-level skills and are thus not within the scope of this project because it would not result in an employee changing occupation titles at the COCS level. Occupational training, or education, provides the employee with a new set of skills that permits him/her to transition to a new COCS occupation title. These are the training costs addressed by the model. Skills-based training must be estimated separately and then incorporated with the cost output from the model.

As part of the input to the Workforce Transition Model, this report provides training-cost estimates. Providing estimates of training costs between each possible combination of occupations is an onerous, if not impossible, task. There are 80 occupation classifications implying 6,320 possible transitions between occupations. Thus, it is necessary to group sets of similar transitions based on available data. This categorization accomplishes two purposes. First, it simplifies data collection by grouping sets of transitions that will have similar costs. For example, estimating the costs of each occupation type within the Laborers and General Services Workers to each occupation within the Technicians category is difficult because it requires significant data collection. Accessible data exists, however, that estimates training any Laborers and General Services Workers to be any Technician costs approximately \$25,000 and 3 months on-the-job-training. These estimates are used as starting points. Each installation will have unique training opportunities that will allow the installation to produce installation-specific, training-cost matrixes.

A second reason for categorizing occupation transitions is to limit the number of variables in the computer model. Fewer variables decrease execution time, and allow using a smaller, less-expensive version of the computer package. Each occupation transition requires a variable; however, occupation transitions that are not permitted need not be included in the model. An example of a prohibited occupation transition is a Laundry Worker training to become a Chemical Engineer. Only transitions that are sure not to occur should be excluded from the model; transitions that are questionable should be included. It is always possible to prevent a transition by imposing an inordinately high training cost.

Occupation transitions are grouped into three categories: 1) prohibited; 2) transitions incurring training costs (with experience and/or without experience); and 3) no-cost. The categories are based on the expense and time required to perform the necessary training. These categories can be viewed as a cost spectrum ranging across unacceptably expensive, expensive, inexpensive, and essentially free. The latter three categories are artificial differences derived from the literature and HR personnel and are merely used as a mechanism to simplify estimating training costs.

Prohibited Transitions

Transitions may be prohibited because 1) it is significantly cheaper to hire a person with the requisite skills than train a current employee into the occupation, 2) the time required to perform the necessary training is beyond the time-horizon of the model, or 3) personnel will not transfer to occupations for which they are significantly over-trained. This is not to say a person cannot train to any occupation they desire; it just states that certain transitions are outside the scope of this model. Using an earlier example, it is possible for a Laundry Worker to train to a Chemical Engineer. The Laundry Worker, however, would not train directly to be a Chemical Engineer. The Laundry Worker would most likely transition through several other occupations, including a Technician occupation, before becoming a Chemical Engineer. These intermediate transitions are of shorter duration and would be included in the model, allowing for career path development.

Following is a delineation of transitions that are and are not allowed. The rules are categorized by occupation family and specify the requirements for training into occupations within each

family, requirements for training to occupations outside of the family, and special requirements for transitioning between specific occupation classifications. Specifying a transition does not imply it has to occur, merely that it may occur. Individual installations may make the cost of certain transitions prohibitive to prevent them from occurring.

Notes: Many rules overlap, therefore any single rule may not fully describe restricted or allowed transitions.

General Managers, Executives, and First Line Supervisors

- Anyone can train to be a First Line Supervisor (of related area: a Secretary will not become First Line Supervisor of Crafts personnel).
- Engineers, Scientists, and Professionals can train to be Project and Program Managers.
- Engineers, Scientists, Professionals, and other Managers can train to be General Managers and Executives.
- General Administrative, Technicians, Crafts, Operators, and Laborers will not be trained to be General Managers and Executives, or Project and Program Managers.
- Any Manager can train to be any other Manager.
- Project and Program Managers and General Managers and Executives can train to be Engineers, Scientists, and Professionals.
- General Managers and Executives or Project and Program Managers will not train to be General Administrative, Technicians, Crafts, Operators, and Laborers.
- First Line Supervisors can train back to the occupation title related to his/her background.

Engineers and Scientists

- Engineers and Scientists may train to any occupation within either family.
- Engineers and Scientists will not train to be General Administrative, Technicians, Crafts, Operators, or Laborers.
- General Administrative, Crafts, Operators, and Laborers will not train to be Engineers or Scientists.
- Crafts and Operators may train to be Plant Engineers.
- Technicians may train to be Engineers or Scientists.

Professionals

- No training will be allowed to or from Accountants and Auditors, Architects, Lawyers, and Physicians.
- Only Security Guards may train to be Safeguards and Security Specialists.

- Anyone, except Administrative, may train to be Buyers, Procurement and Contractor Specialists, Compliance Inspectors, Cost Estimators and Planners and Schedulers, Personnel Training and Labor Relations Specialists, Physician Assistants, Technical Writers and Editors, and Trainers.
- Managers, Engineers, and Scientists will not train to be Physician Assistants.
- Only Managers, Engineers, Scientists, Industrial Hygienists, and Health Physicists may train to be Industrial Hygienists or Health Physicists.
- Only Managers, Engineers, Scientists and Professionals may train to be Communication Specialists.
- Operators, Crafts, and Laborers may not train to be Computer Systems Analysts.
- Any Professional may train to any other Professional occupation except as constrained by other rules.
- Professionals will not train to be Technicians, Crafts, Operators, or Laborers.

General Administrative, Secretarial, and Clerical Support Staff

- Any General Administrative, Secretarial, and Clerical Support Staff may train to any other General Administrative, Secretarial, and Clerical Support Staff occupation.
- General Administrative, Secretarial, and Clerical Support Staff personnel cannot train to any occupation outside of this family except to First Line Supervisors.
- No other occupation will train to be in the General Administrative, Secretarial, and Clerical Support Staff family except First Line Supervisors of comparable background.

Technicians

- Technicians will not train to Crafts, Operators, or Labors.
- Operators and Crafts may train to any Technician occupation.
- Technicians may train to any other Technician category.

Crafts

- Crafts may train to any other Crafts category.

Operators

- Operators will not train to be Laborers except Handlers Helpers and Laborers (Specialized).
- Operators may train to any other Operator occupation.

Laborers and General Services Workers

- Only Firefighters and Security Guards may train to be Technicians.
- Any Laborer may train to any other Laborer occupation.

Transitions with Training Costs

The cost of training into many occupations depends on the trainee's employment background. Certain occupation titles are similar in nature and do not require significant retraining to transfer from one to the other. Other occupations, conversely, may be significantly different and do not provide prerequisite knowledge necessary to train into the new occupation. In these cases, additional training would be necessary.

Most transitions will have some associated training costs. These costs are composed of direct training dollars and the time individuals spend on training. Training time may be either time in the classroom or on-the-job training. In either case, training time must be converted to dollars to be included in the model.

Individual background plays an important role in estimating training costs. Individuals in an occupation classification that have a strong background in the occupation classification they are training to will require significantly less training than someone in an occupation classification with little or no related experience. The prohibited transitions delineated above eliminate training between occupation classifications that are significantly diverse in skill background or produce inordinately high training costs. All other training is grouped into two categories: with experience and without experience. With experience indicates that the trainee's current occupation classification provides significant background knowledge related to the new occupation classification. Without experience indicates that the trainee's current occupation classification provides little applicable knowledge to the new occupation. Basic skills such as reading and writing are considered fundamental to all occupations and are not used to differentiate occupation classifications unless advanced training in these skills is required.

No-Cost Transitions

Finally, there are several closely aligned occupation classifications that require no significant training to transfer between classifications. This is not to say no training costs are incurred. Instead, the training costs may be exclusively on the job, and thus not quantified, or consist only of a few hours of formal training that is insignificant compared to other training programs.

3.2.4 Calculation of Training Costs

The cost of training between occupations is not easily quantified. The COCS's high-level view masks many of the specific requirements of individual occupations. The Workforce Transition Model, however, is not designed to plan individual training. Instead, the Workforce Transition Model is designed to estimate the general cost of transition strategies: is it better to train the current workforce to meet EM requirements, hire employees with the necessary EM skills, or use subcontractors to perform EM?

Estimation of training costs should concentrate mainly on the occupations required for EM, such as Environmental Engineers, Safety Engineers, and Health Physics Technicians. There are several approaches to estimating training costs between occupations: literature review, calculations

based on educational requirements, and surveying training experts. Each approach has advantages and will work best for certain transitions.

The literature offers some insight into training costs. Occupational and training-related periodicals cover many of the transitions in the Workforce Transition Model. There are also many articles reviewing past EM exercises that quantify the necessary skills. In most cases, the literature does not provide explicit costs; instead, skill requirements are defined. Universities, colleges, technical schools, unions, and occupational societies are also good sources of estimating the requirements necessary to become proficient in an occupation.

If training costs cannot be found directly, they can be estimated from the requirements necessary to become proficient in an occupation. This is done using the following steps:

1. Determine the difference in skill requirements between two occupations. This defines the training necessary to train from one occupation to the other.
2. Using educational experts, estimate the amount of course work required to satisfy the difference. For an Electrical Engineer training to be a Mechanical Engineer, the difference may only be several Mechanical Engineering courses because the two disciplines have theoretical similarities and common educational requirements. Training from a Technician to a Mechanical Engineer may require core engineering courses, such as statics and dynamics, in addition to Mechanical Engineering courses. In some cases, training requirements can be equated to courses offered by local colleges or technical schools. In other cases, special courses may be necessary or cheaper to achieve the required training.
3. Consult training sources to estimate the cost of training identified in the previous step.

These steps should be repeated for all transitions that could reasonably occur. Unreasonable transitions are intuitively cost prohibitive. (See earlier section above, Prohibited Transitions.)

3.2.5 Current Workforce Characterization

Establishing the number of employees in each COCS occupation category requires each management and operations contractor to map the contractor-specific occupation titles to the COCS occupation titles. Once this is done, it is a simple procedure to calculate the number of employees in each COCS occupation title.

3.2.6 Projected Workforce Requirements

The projected workforce requirements are the number of employees required in each COCS occupation title to accomplish a particular EM mission. This estimation requires expert knowledge of the installation's waste characterization and of potential technologies for accomplishing the mission. First, the installation must be characterized to determine contaminant levels and the geological, hydrological, and meteorological properties of the installation. Once this is known, the appropriate technologies can be determined to best accomplish the EM mission. Finally, the workforce requirements can be estimated based on the chosen technologies.

The primary factor driving the choice of technologies is the EM mission of the installation. The two extremes are C/C and R/T; myriad alternatives exist between the two. The Workforce Transition Model can help evaluate alternatives by establishing the workforce requirements of various missions.

Estimation of EM workforce requirements is difficult because of the variety of remediation technologies and the lack of characterization at many installations. This is further complicated by the range of remediation technologies applicable to each type of waste. For example, two extreme methods for handling buried waste and soils is Capping and Solvent Extraction. Capping is a containment method that covers the contaminated area with a concrete or other solid material barrier. Solvent Extraction extracts the contaminants using a series of chemical processes. The choice of method is dependent on projected risk, the properties of the soil, the characterization of the waste, and the applicable laws governing the remediation of the waste site.

Review of the literature and several recent remediation projects, however, do provide rough-order-of-magnitude estimates of the FTEs and the distribution of necessary occupations required for general remediation projects. These estimates are generic and do not represent precise estimates. They should only be used when no better estimates are available.

Table 3.1 displays the estimated FTEs per cubic meter of waste required of four categories of waste. These categories are general and each encompasses a variety of remediation methods designed for specific situations. For example, Buried Waste and Soils have over 30 identified remediation methods including Aerobic Biological Treatment, Capping, Excavation, and Vitrification. The values in Table 3.1 represent an average of these methods. These numbers are derived from Beckman et al. 1992; Bernhardt and Owen 1991; Boing et al. 1991; Frain 1991; Francis and Spalding 1991; Lesperance et al. 1992; Montoya 1991; Murphie 1991; Rodman et al. 1992; Schreiber 1989; DOE 1989; and Waite 1992; and manhour estimates provided by PRISM,^(a) a remediation technology estimation tool in development at the Pacific Northwest Laboratory.

Table 3.1. Waste Remediation FTE Requirements Used in Workforce Transition Model (assumes one FTE is equivalent to 1,860 hours)

<u>Waste Category</u>	<u>FTEs per m³ of Waste</u>
Facility D&D - structure removal	0.021000
Facility D&D - structure left intact	0.120000
Buried Waste Treatment	0.004200
Soil Treatment	0.004200
Ground Water Treatment	0.000081
Surface Water Treatment	0.000081

- Facility decontamination and decommissioning (D&D) - structure removal: The D&P of a structure that is subsequently demolished. This entails disposing of equipment, furniture, and other items in the building; cleaning and removal of parochial waste; cleaning of walls, fixtures, and other facility components; demolition of the facility; and removal of facility debris.
- Facility D&D - structure left intact: The D&D of a structure that is left intact for future use. This entails disposing of contaminated equipment, furniture, and other items in the building;

(a) Shay, M. R. October 1993. ARAM/PRISM Environmental Remediation Model, Programmatic Environmental Impact Statement Task, Pacific Northwest Laboratory, Richland, Washington.

cleaning and removal of parochial waste; cleaning of walls, fixtures and other facility components to a habitable level; and removal of waste generated during D&D.

- **Buried Waste Treatment:** Buried waste includes drums, equipment, contaminated concrete, debris, as well as overburden and collateral soil to be removed and processed.
- **Soil Treatment:** Contaminated soil is any soil containing contaminants with concentrations above specified limits. Pond sediment and contaminated soil around buried tanks is considered contaminated soil.
- **Ground Water Treatment:** Ground water encompasses all underground sources of water including aquifers.
- **Surface Water Treatment:** Surface water includes both standing and flowing water sources including natural ponds, storage ponds, rivers, and streams.

Table 3.2 displays the estimated distribution of COCS occupations necessary for EM work. These values are derived from the literature, review of recent remediation projects, and expert opinion. Note that several of the COCS occupations are not included in the EM workforce distribution, such as Geologists and Environmental Science Technicians. This does not imply that these occupations are not part of EM projects. Many of these occupations may be considered overhead occupations or occupations considered interchangeable with other occupations by the data source.

The Percent column in Table 3.2 indicates the distribution of FTEs across occupations. All resulting fractions should be rounded to the next highest integer to identify the number of people per occupation instead of FTEs per occupation. This is necessary for three reasons: first, the high level of abstraction of the COCS precludes one person from belonging to two occupations; second, medium-term planning is easier in terms of people, instead of FTEs; and third, it is easier to identify people to train/hire/lay off than FTEs. The Minimum column in Table 3.2 indicates the minimum number of people in each occupation necessary for a remediation project.

Using Tables 3.1 and 3.2, a rough-order-of-magnitude projected EM workforce can be characterized by estimating the volume of waste in each waste category in Table 3.1. Multiplying the volumes by the FTEs per cubic meter in Table 3.1 and summing the results estimates the total number of FTEs required to remediate a site. The number of people required in each occupation is found by multiplying the total number of FTEs by the percentage of FTEs allocated to each occupation in Table 3.2.

Note that Tables 3.1 and 3.2 may be used to estimate workforce requirements for any size remediation project from a small chemical spill to an entire installation to the DOE complex. Because the values in the tables are rough estimates based on aggregation of many methods and projects, resulting estimates will generally be more accurate for larger projects that require a variety of methods and the processing of large volumes of waste.

Table 3.2. EM Occupational Distribution

Code	COCS Occupation	Percent	Minimum
M010	First Line Supervisors	7.5000	1
M020	General Managers and Executives	1.5000	0
M030	Project and Program Managers	3.0000	0
E010	Chemical Engineers	2.9700	1
E020	Civil Engineers	2.9700	2
E030	Computer Engineers	2.2000	0
E040	Electrical Engineers	0.0000	0
E050	Environmental Engineers	2.9700	0
E060	Industrial Engineers	2.9700	0
E070	Mechanical Engineers	2.9700	0
E080	Nuclear Engineers	2.9700	0
E090	Petroleum/Mining Engineers	0.0000	0
E100	Plant Engineers	1.5400	1
E110	Quality Control Engineers	0.2200	0
E120	Safety Engineers	0.2200	0
S010	Chemists	0.7000	0
S020	Environmental Scientists	0.7000	0
S030	Geologists	0.0000	0
S040	Life Scientists	0.4500	0
S050	Materials Scientists	0.0000	0
S060	Mathematicians	0.0000	0
S070	Physicists	0.7000	0
S080	Social Scientists	0.4500	0
P010	Accountants And Auditors	1.0725	0
P020	Architects	0.0000	0
P030	Buyers, Procurement And Contracting Specialists	2.0800	0
P040	Communication Specialists	0.0000	0
P050	Compliance Inspectors	1.0725	0
P060	Computer Systems Analysts	1.0725	0
P070	Cost Estimators And Planners And Schedulers	2.4700	0
P080	Health Physicists	0.6500	0
P090	Industrial Hygienists	0.6500	0
P100	Lawyers	0.3900	0
P110	Personnel And Labor Relations Specialists	1.1700	0
P120	Physicians	0.0000	0
P130	Physician Assistants, Nurses And Other Medical	0.0000	0
P140	Safeguards And Other Security Specialists	0.0000	0
P150	Trainers	1.3000	0
P160	Technical Writers And Editors	1.0725	0
G010	Administrative Assistants	0.0000	0
G020	Office Clerks (General)	4.4000	0
G030	Office Clerks (Specialized)	1.1000	0
G040	Secretaries	4.4000	0
G050	Typists And Word Processors	1.1000	0
T010	Computer Operators/Coders	0.0000	0
T020	Drafters	2.2800	0

Table 3.2. (contd)

Code	COCs Occupation	Percent	Minimum
T030	Engineering Technicians	0.0000	0
T040	Environmental Sciences Technicians	0.0000	0
T050	Health Physics Technicians	2.4000	2
T060	Industrial Safety And Health Technicians	2.5200	0
T070	Instrument And Control Technicians	2.4000	0
T080	Laboratory Technicians	2.4000	0
T090	Media Technicians	0.0000	0
T100	Survey And Mapping Technicians	0.0000	0
C010	Carpenters	0.8000	0
C020	Electricians	1.4000	0
C030	Heating Air/Conditioning And Refrigeration Mech.	0.8000	0
C040	Machinists	1.2000	0
C050	Masons	0.8000	0
C060	Millwrights	1.2000	0
C070	Painters	0.0000	0
C080	Plumbers And Pipefitters	2.2000	1
C090	Structural And Metal Workers	0.8000	0
C100	Vehicle And Mobile Equipment Mechanics	0.0000	0
C110	Welders	0.8000	0
R010	Chemical System Operators	0.0000	0
R020	Drillers	0.6667	0
R030	Material Moving Equipment Operators	0.6667	1
R040	Nuclear Plant Operators	0.0000	0
R050	Nuclear Waste Process Operators	0.0000	0
R060	Production Systems Operators	0.0000	0
R070	Utilities Systems Operators	0.6666	0
L010	Firefighters	0.0000	0
L020	Food Service Workers	0.0000	0
L030	Janitors And Cleaners	4.5000	0
L040	Laundry Workers	1.3500	0
L050	Material Handlers, Helpers And Laborers (General)	0.9000	0
L060	Material Handlers, Helpers And Laborers (Specialized)	6.0000	2
L070	Light Vehicle Drivers	0.0000	0
L080	Security Guards	2.2500	0

3.3 The Model

The Workforce Transition Model uses training, hiring, and layoff costs to determine the optimal transition strategy. This section discusses relevant linear programming issues, presents a simple demonstrative model, and then presents the model implementation.

3.3.1 The Linear Program

The formulation of this model is characteristic of the common assignment problem, a special case of a linear programming (LP) model. See Appendix B for a discussion of Linear Programming (also see Bradley et al. 1977). In an assignment problem, the object is to find the minimum

total weight assignment of n objects to m locations given the weights w_{ij} of assigning object i to location j (Parker and Rardin 1988). In this case, the current workforce distribution are the n objects, the projected workforce requirements are the m locations, and the transition costs are the weights. The goal is to minimize the cost of assigning the employees in the current workforce to the occupation positions specified in the projected workforce.

Linear programming models consist of two components: the objective function and a set of constraints. The objective function defines the criteria for determining the optimal solution. The constraints define resource limitations.

The Objective Function

The Workforce Transition Model possesses three methods for implementing the transition from the current workforce to the projected workforce: 1) employees may train from one occupation to another, most likely from an occupation category that has an excess number of employees to an occupation category with a shortage of employees; 2) employees may be laid off, most likely from occupation categories with an excess number of employees; or 3) new employees may be hired, most likely into occupation categories with a shortage of employees. The objective function defines a weighted relationship among these methods. For the Workforce Transition Model, the goal is to minimize the cost of the transition, and the weights assigned to each method are the associated costs. The objective function is:

Minimize:

$$\sum_{i=1}^n \sum_{\substack{j=1 \\ i \neq j}}^n X_{ij}x_{ij} + \sum_{i=1}^n H_i h_i + \sum_{i=1}^n T_i t_i \quad (3.1)$$

where:

- n = number of occupations in model
- i, j = occupation indexes
- X_{ij} = cost of training an employee from occupation i to occupation j
- x_{ij} = number employees training from occupation i to occupation j
- H_i = cost of hiring a person into occupation i
- h_i = number of employees hired into occupation i
- T_i = cost of laying off a person in occupation i
- t_i = number of employees laid off from occupation i

$$\sum_{i=1}^n \sum_{\substack{j=1 \\ i \neq j}}^n X_{ij}x_{ij} = \text{total training costs}$$

$$\sum_{i=1}^n H_i h_i = \text{total hiring costs}$$

$$\sum_{i=1}^n T_i t_i = \text{total layoff costs.}$$

Constraints

There are two types of constraints in the Workforce Transition Model: employee-balance equations and non-negativity constraints. The employee-balance equations are a special type of mass-balance equations that ensure that the appropriate number of people end up in each occupation category. The number of employees in each occupation title before and after the transition may be written as a series of balance equations for each occupation title:

$$\begin{aligned}
 x_{1,a} &= x_{1,b} + x_{2,1} + x_{3,1} + \dots + x_{n,1} - x_{1,2} - x_{1,3} - \dots - x_{1,n} \\
 x_{2,a} &= x_{2,b} + x_{1,2} + x_{3,2} + \dots + x_{n,2} - x_{2,1} - x_{2,3} - \dots - x_{2,n} \\
 &\vdots \\
 x_{n,a} &= x_{n,b} + x_{1,n} + x_{2,n} + \dots + x_{n-1,n} - x_{n,1} - x_{n,2} - \dots - x_{n,n-1}
 \end{aligned} \tag{3.2}$$

where:

- i = occupation index
- $x_{i,a}$ = number employees in occupation i after transition
- $x_{i,b}$ = number of employees in occupation i before transition
- $x_{1,i}, x_{2,i}, \dots$ = number of employees training from all other occupations to occupation i
- $x_{i,1}, x_{i,2}, \dots$ = number of employees training from occupation i to each other occupation.

This can be rewritten as:

$$\sum_{\substack{j=1 \\ i \neq j}}^n x_{ji} - \sum_{\substack{j=1 \\ i \neq j}}^n x_{ij} = \Delta_i \quad i = 1, 2, \dots, n \tag{3.3}$$

where:

- i, j = occupation indexes
- Δ_i = $x_{i,b} - x_{i,a}$, or the change in the number of employees in occupation i
- x_{ji} = number of employees training from occupation j to occupation i
- x_{ij} = number of employees training from occupation i to occupation j .

The current workforce and projected workforce requirements by themselves represent a closed system. This is not representative of the real system because employees may enter or exit the installation workforce. To account for these movements, n additional objects and m additional locations must be defined to represent the source of new hires and the sink of terminated employees. Including hiring and layoffs, Equation (3.3) is rewritten as:

$$\sum_{\substack{j=1 \\ i \neq j}}^n x_{ji} - \sum_{\substack{j=1 \\ i \neq j}}^n x_{ij} + h_i - t_i = \Delta_i \quad i = 1, 2, \dots, n \tag{3.4}$$

where:

- h_i = number of new hires in occupation i
- t_i = number of employees in occupation i terminated.

The non-negativity constraints prevent unrealistic behavior such as hiring a negative number of people. This is undesirable because hiring a negative number of people is equivalent to laying off people and there is a set of variables for that purpose. The non-negativity constraints are:

$$\begin{aligned} x_{ij} &\geq 0 \\ h_i &\geq 0 \\ t_i &\geq 0. \end{aligned} \tag{3.5}$$

Additional Constraints

Additional constraints may be added as warranted. One type of constraint that may be necessary is the limitation of transitions related to an occupation classification. An example limitation constraint is:

$$x_{ij} \leq x_{ij,max} \quad i = 1, 2, \dots, n; \quad j = 1, 2, \dots, n \tag{3.6}$$

$$x_{ij} \geq x_{ij,min} \quad i = 1, 2, \dots, n; \quad j = 1, 2, \dots, n \tag{3.7}$$

where

$x_{ij,max}$ = the maximum number of employees allowed to train from occupation i to occupation j

$x_{ij,min}$ = the minimum number of employees allowed to train from occupation i to occupation j .

This would occur when maintaining career paths or occupation continuity and it is necessary to ensure a minimum number of employees stay in a certain occupation classification. A situation that may cause an unsatisfactory high level of occupation transitions is when the cost of training a person from occupation a to occupation b and the hiring cost for replacing the person lost in occupation a is less than the cost of hiring a person directly into occupation b , or:

$$X_{ab} + H_a < H_b \tag{3.8}$$

This would occur through an infrequent combination of parameters. One such combination is when there are two occupation classifications where occupation a has the correct number of people and occupation b needs one more person. The cost to hire a person into b , however, is less than the cost to train a person from a to b and hire a new person to a to replace the person trained to b . This may occur when an hourly person has the opportunity to train into an exempt occupation, because hiring costs for an exempt employee are significantly higher than hiring costs for an hourly employee. If the training costs are less than the difference in hiring costs, the model will determine it is better to take the training option than hire a b directly. In small numbers, this domino effect may be acceptable. In large numbers, however, it may need to be curtailed to prevent large-scale occupation turnover.

The Complete Model

Combining the objective function and the constraints the complete LP formulation is:

Minimize:

$$\sum_{i=1}^n \sum_{\substack{j=1 \\ i \neq j}}^n X_{ij} x_{ij} + \sum_{i=1}^n H_i h_i + \sum_{i=1}^n T_i t_i \quad (3.9)$$

such that:

$$\sum_{\substack{j=1 \\ i \neq j}}^n x_{ji} - \sum_{\substack{j=1 \\ i \neq j}}^n x_{ij} + h_i - t_i = \Delta_i \quad i = 1, 2, \dots, n$$

$$x_{ij} \geq x_{ij,\min} \quad i = 1, 2, \dots, n; \quad j = 1, 2, \dots, n$$

$$x_{ij} \leq x_{ij,\max} \quad i = 1, 2, \dots, n; \quad j = 1, 2, \dots, n$$

$$x_{ij} \geq 0 \quad i = 1, 2, \dots, n; \quad j = 1, 2, \dots, n$$

$$h_i \geq 0 \quad i = 1, 2, \dots, n$$

$$t_i \geq 0 \quad i = 1, 2, \dots, n$$

3.3.2 Example Model

This section demonstrates the model using a small fragment of the actual Workforce Transition Model. Only two occupation titles are used because a two-dimensional LP can be demonstrated graphically. The parameter values are hypothetical and are altered as necessary for demonstrative purposes.

Assume there are two occupation types: Engineering Technicians and Health Physics Technicians. The following table indicates the current (1993) and future (1997) needs for each occupation type.

Table 3.3. Workforce Example Levels

	Current Levels (1993)	Projected Requirements (1997)
Engineering Technicians	10	7
Health Physics Technicians	8	13

This indicates that 3 Engineering Technicians must be released and 5 Health Physics Technicians need to be obtained. There are several ways to do this. The first is to layoff the Engineering Technicians and hire new Health Physics Technicians. An alternative is to train all of the Engineering Technicians to be Health Physics Technicians; then only 2 Health Physics

Technicians need to be hired externally. The advantage of this option is that it avoids layoffs. To determine which solution is better, training, hiring, and layoff costs must be compared.

The training costs to train from one occupation to another are shown in Table 3.4:

Table 3.4. Workforce Example Training Costs

	<u>Engineering Technicians</u>	<u>Health Physics Technicians</u>
Engineering Technicians	\$0	\$34,000
Health Physics Technicians	\$34,000	\$0

Other costs are:

Hire Engineering Technicians:	\$10,000/person
Hire Health Physics Technicians:	\$10,000/person
Lay off Engineering Technicians:	\$14,000/person
Lay off Health Physics Technicians:	\$14,000/person

The variables used in this model are:

- x12 number of Engineering Technicians training to be Health Physics Technicians
- x21 number of Health Physics Technicians training to be Engineering Technicians
- h1 number of Engineering Technicians hired externally
- h2 number of Health Physics Technicians hired externally
- t1 number of Engineering Technicians laid off
- t2 number of Health Physics Technicians laid off.

The objective is to minimize the total training, hiring, and layoff costs. The formulation of the linear program is:

$$\text{Minimize } 34000x_{12} + 34000x_{21} + 10000h_1 + 10000h_2 + 14000t_1 + 14000t_2$$

Such that

$$\begin{aligned} -x_{12} + x_{21} + h_1 - t_1 &= -3 \\ x_{12} - x_{21} + h_2 - t_2 &= 5. \end{aligned}$$

The optimal solution to this problem is to lay off 3 Engineering Technicians and hire 5 Health Physics Technicians. The total cost would be \$92,000.

Alternatively, if the cost to train Engineering Technicians to be Health Physics Technicians and Health Physics Technicians to be Engineering Technicians is \$24,000 (instead of \$34,000), then the optimal solution is to train 3 engineering Technicians to be Health Physics Technicians and hire 2 Health Physics Technicians. The total cost also would be \$92,000.

In another alternative, if the cost to train Engineering Technicians to be Health Physics Technicians and Health Physics Technicians to be Engineering Technicians is \$24,000 (instead of \$34,000) and the hiring costs for Health Physics Technicians is \$34,000 (instead of \$10,000), then the optimal solution would be to train 5 Engineering Technicians to be Health Physics Technicians and hire 2 Engineering Technicians. The total cost would be \$140,000.

Additional constraints can easily be added. For example, assume that there is a planned RIF in 1996 and one Engineering Technician and 2 Health Physics Technician are laid off. This is modeled by adding the following two constraints:

$$\begin{aligned}t_1 &\geq 1 \\t_2 &\geq 2.\end{aligned}$$

The optimal solution is now to train 1 Engineering Technician to be a Health Physics Technician, hire 5 Health Physics Technicians, lay off 2 Engineering Technicians, and lay off 1 Health Physics Technician. This would cost \$31,500. These two additional constraints lead to a total costs of \$116,000, \$24,000 more than the original problem without forced layoffs (116,000 - 92,000).

To meet the projected requirements, 3 additional people must be hired to replace the 3 employees laid off in 1996. This is a better solution only if the savings garnered from not paying the 3 employees is more than the additional costs resulting from the forced RIF. This variation demonstrates how this model can be used to analyze RIF plans.

These alternatives show how changes in costs impact the optimal solution. They do not explicitly incorporate the undesirable effect of layoffs. This effect must be added so that alternatives with layoffs are penalized per the National Defense Authorization Act for Fiscal Year 1993 (Public Law 102-484).

4.0 Workforce Budget Constraint Model

The Workforce Budget Constraint Model helps estimate the number of personnel that will be laid off given a workforce budget reduction and assists in identifying how the layoffs should be distributed across the COCS occupations. The Workforce Budget Constraint Model requires aggregate workforce salary and characterization data based on the COCS. Specifically, the model requires:

- average salary for each COCS occupation title
- other layoff-related savings/costs for each COCS occupation title
- projected number of nonessential personnel in each COCS occupation title given a specific scenario.

The average salary is calculated as the average salary of all employees in a COCS class.

Other layoff-related savings/costs is a catchall for other savings and costs that will be incurred when the personnel reduction occurs. For example, salary is only part of the compensation package each employee receives: retirement and health benefits are two other sources of savings resulting from layoffs. Large RIFs may also cause some increases in costs. For example, there may be an increased need to subcontract some work. These savings and costs should be reoccurring, and should not be a single savings/cost resulting from implementing the RIF, such as severance packages.

Identifying the number of nonessential personnel in each COCS is the most complicated task. This will require surveying managers and determining reductions in COCS categories that will least affect operations.

4.1 The Objective Function

The objective of the Workforce Budget Reduction Model is to identify the minimum number of people to lay off. The objective function is:

Minimize:

$$\sum_{i=1}^n S_i x_i + \sum_{i=1}^n O_i x_i \quad (4.1)$$

where

- i = occupation index
- S_i = average salary of occupation i
- x_i = number of employees identified for RIF in occupation i
- O_i = other occupation i related costs.

4.2 Constraints

There are two constraints in the Workforce Budget Reduction Model. The first is the maximum number of employees in each occupation that can be released. The second is the budget reduction amount. These constraints are respectively:

$$x_i \leq P_i \quad (4.2)$$

where

P_i = maximum number of employees that can be released in occupation i .

$$\sum_{i=1}^n S_i x_i + \sum_{i=1}^n O_i x_i \geq BR \quad (4.3)$$

where

BR = budget reduction amount.

Notice that the second constraint, Equation (4.3), provides a lower limit to the objective function, Equation (4.1). This combination ensures that the solution is as close to the budget reduction requirement without going under, analogous to the Price Is Right rules.

4.3 The Complete Model

Combining the objective function and the constraints, the LP formulation is:

Minimize:

$$\sum_{i=1}^n S_i x_i + \sum_{i=1}^n O_i x_i \quad (4.4)$$

such that:

$$x_i \leq P_i$$

$$\sum_{i=1}^n S_i x_i + \sum_{i=1}^n O_i x_i \geq BR \quad (4.5)$$

$$x_i \geq 0$$

5.0 Computer Implementation

The Workforce Transition Model and the Workforce Budget Reduction Model are implemented in the Workforce Transition Modeling Environment (WFTME) software application. The two components of the WFTME are the user interface and the linear programming application. Common off-the-shelf packages (COTS) were chosen to implement these components because they streamlined the development process. COTS shorten the development time, decrease the development costs, and increase the perceived quality of the product because previously tested code is used. The Linear Programming component is supplied by Resource Optimization Inc.'s (ROI) XPRESS-MP (1993). The user interface is built using Microsoft's FoxPro Relational Database Management System. Refer to the *Workforce Transition Modeling Environment User's Guide*, PNL-8917, (Stahlman et al. 1993) for a description of the computer implementation and how to operate the Workforce Transition Model.

This Workforce Transition Model contains 80 constraints and about 4500 variables. Each constraint represents a mass-balance equation for each occupation classification. There are 6560 possible variables: 80 variables representing hiring costs for each occupation classification; 80 variables representing layoff costs for each occupation classification; and 6400 variables representing training transitions.

Two reasons precipitate the exclusion of many of the training variables to pair the model from 6560 variables to about 4500 variables. First, many of the transitions will never occur, and thus do not need to be included in the model. They could be included with arbitrarily high training costs to prevent the transition from being part of the optimal solution. Data input is simplified, however, if these training costs are omitted from the input spreadsheet. The second reason is to allow the use of a less expensive version of XPRESS. The XPRESS professional version, currently used, allows a combined maximum of 5000 constraints and variables. This version costs approximately \$3,000. The XPRESS extended version allows unlimited sized models, but costs approximately \$7,500. ROI allows upgrading to the extended version for only the price difference so there is no risk in using the smaller version. The Lotus 123 driver is also required and costs approximately \$500.

6.0 Conclusions

This report presents two models to assist medium-term workforce planning. The first model, the Workforce Transition Model, helps estimate the cost of transitioning the current workforce to a projected workforce that will meet the changing needs of the organization. The second model, the Workforce Budget Constraint Model, is short term and assesses the impact of a workforce-budget reduction. The two models are implemented using Linear Programming (LP) in the Workforce Transition Modeling Environment.

These models are the first step to comprehensive workforce planning. The data necessary to use the models are as critical as the results the model generates. The input data also provide valuable input to other aspects of workforce planning. These data include projected workforce requirements, site characterization, the EM transition schedule, and transition-related costs. The next step is to develop and implement standardized processes to gather or estimate this critical data. One approach is to use related DOE work that is characterizing waste sites in the DOE complex and estimating appropriate remedies. One output of these projects, Re-Opt and PRISM, is FTE estimates. If the FTE estimates can be broken down according to the COCS, a reliable estimate of EM workforce requirements can be developed. This information will provide DOE the ability to estimate the cost and time required of various remediation strategies at the installation level and the DOE complex level.

Future work on this project should be conducted in three areas. First, the Workforce Transition Model should be disseminated throughout the DOE complex. This will enhance commonality and facilitate integrated workforce planning. Second, the computer implementation of these models should be enhanced to increase flexibility and ease of use. Finally, the scope of the project should be expanded to include additional components of workforce planning. This includes the ability to incorporate subcontracting alternatives, Equal Employment Opportunity (EEO) considerations, Waste Management, Defense Production and other concurrent missions, intra-occupation transition costs, transition schedules, links to short-term workforce planning, and other workforce planning functions.

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Appendix A

Common Occupation Classification System (COCS)

Appendix A

Common Occupation Classification System (COCS)

Attempts by DOE's Office of Environmental Restoration and Waste Management (EM) to plan for the likely future workforce have been made difficult due to the lack of a consistent set of occupational titles and definitions across the complex. Two reasons for this difficulty may be cited. First, classification systems commonly used in industry often fail to cover in sufficient depth the unique demands of the nuclear energy and research community. Second, the government practice of contracting the operation of government facilities to the private sector has introduced numerous contractor-specific classification schemes to the DOE complex. As a result, sites/contractors report their workforce needs using unique classification systems. It becomes difficult, therefore, to roll these data up to the national level necessary to support strategic planning and analysis.

The COCS is designed to overcome these workforce planning barriers. The COCS is based on earlier workforce planning activities and the input of workforce planning and human resource managers from across the DOE complex. It provides a set of mutually exclusive job titles and definitions that cover the broad range of activities present in the DOE complex. The COCS is not a required record-keeping or data management guide. Neither is it intended to replace contractor/DOE-specific classification systems. Instead, the system is designed to standardize workforce requirements reporting by crosswalking--mapping on to--current contractor databases.

The COCS consists of 80 occupation titles broken into 9 families. The occupation and family titles are given in Table A.1. Each occupation and family title is assigned a four-character code for easy reference. These codes were used throughout this document.

Table A.1. COCS Occupation Titles and Family Titles

M000	GENERAL MANAGERS, EXECUTIVES, FIRST LINE SUPERVISORS AND PROGRAM/PROJECT MANAGERS
M010	First Line Supervisors
M020	General Managers And Executives
M030	Project And Program Managers
M040	Other Managers

Table A.1. (contd)

E000 ENGINEERS

E010	Chemical Engineers
E020	Civil Engineers
E030	Computer Engineers
E040	Electrical Engineers
E050	Environmental Engineers
E060	Industrial Engineers
E070	Mechanical Engineers
E080	Nuclear Engineers
E090	Petroleum/Mining Engineers
E100	Plant Engineers
E110	Quality Control Engineers
E120	Safety Engineers
E130	Other Engineers

S000 SCIENTISTS

S010	Chemists
S020	Environmental Scientists
S030	Geologists
S040	Life Scientists
S050	Materials Scientists
S060	Mathematicians
S070	Physicists
S080	Social Scientists
S090	Other Scientists

P000 ADMINISTRATIVE AND OTHER PROFESSIONAL OCCUPATIONS

P010	Accountants And Auditors
P020	Architects
P030	Buyers, Procurement And Contracting Specialists
P040	Communication Specialists
P050	Compliance Inspectors
P060	Computer Systems Analysts
P070	Cost Estimators And Planners And Schedulers
P080	Health Physicists
P090	Industrial Hygienists
P100	Lawyers
P110	Personnel And Labor Relations Specialists
P120	Physicians
P130	Physician Assistants, Nurses And Other Medical Support Occupations
P140	Safeguards And Other Security Specialists
P150	Trainers
P160	Technical Writers And Editors
P170	Other Administrative And Professional Other Occupations

Table A.1. (contd)

G000 GENERAL ADMINISTRATIVE, SECRETARIAL AND CLERICAL SUPPORT STAFF

G010	Administrative Assistants
G020	Office Clerks (General)
G030	Office Clerks (Specialized)
G040	Secretaries
G050	Typists And Word Processors
G060	Other General Administrative, Secretarial And Clerical Support Staff

T000 TECHNICIANS

T010	Computer Operators/Coders
T020	Drafters
T030	Engineering Technicians
T040	Environmental Sciences Technicians
T050	Health Physics Technicians
T060	Industrial Safety And Health Technicians
T070	Instrument And Control Technicians
T080	Laboratory Technicians
T090	Media Technicians
T100	Survey And Mapping Technicians
T110	Other Technicians

C000 CRAFTS

C010	Carpenters
C020	Electricians
C030	Heating Air-Conditioning And Refrigeration Mechanics (HVAC)
C040	Machinists
C050	Masons
C060	Millwrights
C070	Painters
C080	Plumbers And Pipefitters
C090	Structural And Metal Workers
C100	Vehicle And Mobile Equipment Mechanics
C110	Welders
C120	Other Crafts

R000 OPERATORS

R010	Chemical System Operators
R020	Drillers
R030	Material Moving Equipment Operators
R040	Nuclear Plant Operators
R050	Nuclear Waste Process Operators
R060	Production Systems Operators
R070	Utilities Systems Operators
R080	Other Operators

Table A.1. (contd)

L000 LABORERS

L010	Firefighters
L020	Food Service Workers
L030	Janitors And Cleaners
L040	Laundry Workers
L050	Material Handlers, Helpers And Laborers (General)
L060	Material Handlers, Helpers And Laborers (Specialized)
L070	Light Vehicle Drivers
L080	Security Guards
L090	Other Laborers and General Services Workers

Appendix B

Linear Programming Primer

Appendix B

Linear Programming Primer

This section provides a brief introduction to Linear Programming (LP) designed to acquaint the reader with basic concepts and an understanding of what linear programming is. It is not meant to be a tutorial.

B.1 Overview

LP is a technique for efficiently finding a solution to a series of linear equations that will either minimize or maximize a linear objective function. LP is typically applied to resource allocation problems where limited resources are distributed among multiple, competing demands (objects). The constraints on each resource are formulated as a series of linear equations along with an objective function defining what characteristics to optimize.

The linear equations are called constraints and define the universe of feasible solutions called the feasible region. The feasible region represents all possible solutions that will satisfy all of the constraints simultaneously. The objective function is a linear relationship of one or more of the variables in the constraints that is to be optimized (maximized or minimized). The objective function is used to define which point within the feasible region is the optimal solution. The generic form of an LP model is:

minimize (or maximize)	$\sum_{j=1}^n c_j x_j$	Objective function
such that	$\sum_{j=1}^n a_{ij} x_j \geq b_i \quad \text{for } i = 1, 2, \dots, m$	Resource constraints
	$x_j \geq 0 \quad \text{for } j = 1, 2, \dots, n$	Non-negativity constraints

where:

x_j are system variables
 c_j are objective function weights
 a_{ij} are constraint weights
 b_i are constraint, or resource, limits.

The non-negativity constraints are implicit in most resource allocation problems; this prevents the existence of a negative number of objects that are demanding resources.

If there is no solution that will satisfy all of the constraints simultaneously, the solution is infeasible. The following two constraints define a problem with an infeasible solution:

$x > 5$, and
 $x < 2$.

There are a variety of special forms of LPs. One general category is Integer Programming models or Mixed-Integer Programming models (IP or MP), where one or more variables are restricted to integer values. These types of problems require additional techniques beyond the simplex method to identify the optimal solution because the simplex method treats all variables as decimals.

B.2 A Linear Programming Example

An example LP formulation is:

Maximize:	
$2x_1 + x_2$	Objective function
Such that:	
$x_1 \leq 3$	Constraint 1
$x_2 \leq 4$	Constraint 2
$x_1 + x_2 \leq 4$	Constraint 3
$x_1, x_2 \geq 0$	Non-negativity constraints

Figure B.1 demonstrates the constraints and feasible region for this example.

Figure B.2 demonstrates finding the optimal solution by graphically moving the objective function across in the feasible region. The value of the objective function increases as it moves right and up. Where the objective function crosses $x_1 = 2$ (O_1), the objective function equals 4. This is true for all points along the objective function; however, only the portion of the objective function falling within the feasible region produces feasible solutions. Where the objective function crosses $x_1 = 4$ (O_2), the objective function equals 6. This represents an increase in the objective function. As the objective function is moved further to the right so that it intersects the feasible region at only the point (3,2) (O_3), the objective function equals 8. The objective function cannot be increased any further without leaving the feasible region; therefore, the optimal solution has been found.

Note that the optimal solution occurs at a corner point, or vertex, of the feasible region. This illustrates the general property of LP that if an optimal solution exists, there is always a vertex in the optimal solution. In most cases, there is only one feasible optimal solution. The only exception to this is when the objective function is parallel to a constraint. In this case, as demonstrated in Figure B.3., there is an infinite number of solutions where the objective function borders the feasible region. There also are two vertices in the optimal solution.

B.3 General Solution to Linear Programs

Obviously, problems involving more than two variables cannot be solved graphically and exhaustive enumeration is not practical. The simplex algorithm, developed by George Dantzig in the 1940s for solving linear programs, takes advantage of the vertex property to quickly and efficiently find the optimal solution by only testing vertex solutions.

Figure B.1. Graphical Representation of Linear Program (feasible region is shaded)

Figure B.2. Graphical Optimization of Example LP

Figure B.3. Optimal Solution When Objective Function Is Parallel to a Constraint

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